TRAINING PROGRAMME
ON
ENERGY MANAGEMENT
AT
MACNEILL AND MAGOR LIMITED, ASSAM

FEBRUARY 26 & 28, 1990

READING MATERIAL

Prepared by

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Conducted by

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Tata Energy Research Institute
New Delhi

Training Programme on Energy Management at Macneill and Magor Limited
Bishnauth Club, North Bank, Assam

Time-Table

February 26, 1990

10:00 - 10:15	Inaugural Session Welcome Address by Mr. Tarlochan Singh, M&M Inaugural Address by Mr.Prabhir Das, Advisor, M&M Vote of Thanks by Mr. G. Sambasivan, TERI
10:15 - 10:40	Introduction to Programme, and Energy Data Analysis and Results for M&M's Tea Factories by Mr. G. Sambasivan
10:40 - 10:55	Industrial Energy Consumption, Conservation and Policies by Mr. G. Sambasivan
10:55 - 11:10	Tea/Coffee
11:10 - 11:30	Enterprise-Level Energy Management by Mr. S. Anand
11:30 - 11:50	Energy Audit by Mr. G. Sambasivan
11:50 - 12:30	Thermal Energy Conservation - Concepts by Mr. G. Sambasivan
12:30 - 1:30	Lunch
1:30 - 2:30	Electrical Energy Conservation - Concepts by Mr. S. Anand
2:30 - 3:15	Electrical Energy Conservation in Motors by Mr. S. Anand
3:15 - 3:30	Concluding Remarks by Mr. G. Sambasivan

Tata Energy Research Institute
New Delhi

Training Programme on Energy Management at Macneill and Magor Limited Tingri Club, South Bank, Assam

Time-Table

February 28, 1990

8:30 - 9:00	Inaugural Session Welcome and Inaugural Address by Mr. G.S. Sodhi, Advisor, M&M Vote of Thanks by Mr. G. Sambasivan, TERI
9:00 - 9:30	Introduction to Programme, and Energy Data Analysis and Results for M&M's Tea Factories by Mr. G. Sambasivan
9:30 - 9:45	Industrial Energy Consumption, Conservation and Policies by Mr. G. Sambasivan
9:45 - 10:00	Tea/Coffee
10:00 - 10:30	Enterprise-Level Energy Management by Mr. S. Anand
10:30 - 11:00	Energy Audit by Mr. G. Sambasivan
11:00 - 12:30	Thermal Energy Conservation - Concepts by Mr. G. Sambasivan
12:30 - 1:30	Lunch
1:30 - 2:45	Electrical Energy Conservation - Concepts by Mr. S. Anand
2:45 - 3:45	Electrical Energy Conservation in Motors by Mr. S. Anand
3:45 - 4:00	Concluding Remarks by Mr. G. Sambasivan

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Training Programme on Energy Management at Macneill and Magor Tea Estates, Assam

February 26 & 28, 1990

INTRODUCTION

Energy is a vital input for industrial production, and many other human activities. Though energy is not an end in itself, it is a means to an end. Man has evolved in the usage of energy from biomass including fuelwood to fossil fuels. After the two oil crises in the seventies, the world has realized that fossil fuels are finite resources and hence exhaustible, and there is a need to use energy efficiently, in whatever form it comes in.

Industry has been the main target of energy management as its consumption is the largest in any industrialized country, and the sector is more organized. In India, the manufacturing industry accounts for over 51 per cent of the total commercial energy consumption. In contrast to many developed and some developing countries, energy efficiency in our energy sectors, and industry in particular has been low. Consequently, there is a large scope for saving substantial quantities of energy in our industry.

Energy management in a broad sense would mean producing a given quantity of product with minimal energy input (energy conservation), and changing to a more readily available fuel/energy source from the scarcer ones (fuel substitution).

In an energy management programme in any organization or factory, involvement of all employees towards a common goal of higher energy efficiency is of paramount importance. This is achieved effectively through publicity and awareness campaigns, and training programmes.

In response to a request from Mr. M.P.S.Sidhu of Macneill and Magor Limited, Tea Division, the Tata Energy Research Institute, New Delhi proposed that they would conduct a training programme on energy management for employees of the tea estates. This was accepted by Macneill and Magor in August 1989.

In October 1989, Mr. G.Sambasivan and Mr. S.Anand of TERI visited the tea estates at Dekorai, Bargang, Monabarrie and Pertabghur, to study the energy consumption pattern and the scope of energy conservation in the tea factories.

A copy of the Report on Visit to Tea Estates is given in Appendix 1.

Design of the Training Programme. The one-day training programme has been designed to suit the requirements of the tea estates/factories, taking into consideration various areas of coverage requested by Mr. Sidhu in his letter to Mr. G. Sambasivan, dated August 21, 1989. The reading material incorporates various measures for energy management at the corporate and estate levels.

The emphasis in the training programme would be on thermal and electrical energy conservation. The topics are provided in the time-table. The reading material provides additional information on lubrication and training for energy efficiency, and bibliography.

It is expected that a formal energy management structure and programme would be set up at the Tea Division of Macneill and Magor Limited as a sequel to this training programme. An organized energy management programme would ensure energy savings in the short and also long term.

APPENDIX 1

Tata Energy Research Institute
New Delhi

REPORT ON

VISIT TO TEA ESTATES OF MCNEILL & MAGOR LIMITED IN ASSAM

Mr. G. Sambasivan and Mr. S. Anand of Tata Energy Research Institute, New Delhi visited the following tea estates as a part of preparation for the training programme on energy management that TERI has proposed to conduct for Mcneill and Magor (MM) in February 1990.

Date	Place	Factory	Personnel Met
October 3, 1989	Pertabghur		Mr. Tarlochan Singh
	Dekorai	Dekorai	Mr. D.C. Bhandari
			Mr. S. Basu
October 4, 1989	Dekorai	Dekorai	
	Bargang	Bargang	Mr. Nisshad Ahmad
			Mr. Sardul Singh
	Monabarie	Monabarie	Mr. M.M. Singh
			Mr. Nissar Hussain
	Pertabghur		
October 5, 1989	Pertabghur	Pertabghur	Mr. A. Saxena
			Mr. David Taylor
			Mr. M.S. Gill

After arriving at Pertabghur by the Company's aircraft, Mr.Sambasivan and Mr.Anand met Mr.Tarlochan Singh, Touring Engineer stationed at Pertabghur. Mr. Singh provided details on the pattern of energy consumption at the tea estates, made tea production quantities for a few estates, tea making process and the organizational set-up for the Company and its tea estates.

For production of made tea, the factories work for roughly 9 months in a year using electricity purchased from the state electricity board, HSDO/LDO in DG sets for captive power generation and furnace oil (also known as tea dryer oil) in dryers. Every tea factory of MM in Assam has an HT supply line from ASEB. Due to power cuts, MM runs its factories with power from DG sets which operate in the range of 1000-3000 h per year.

Monabarie represents the largest tea factory managed by MM, which makes 30 lakh kg of tea/year. The factories at Dekorai, Bargang and Pertabghur make 15 lakh, 20 lakh and 20 lakh kg. made tea per year respectively.

The processing consists of the following operations: withering, rolling, crushing/tearing/curling, fermenting, drying and packing. Withering and drying are the most energy-intensive processes. While withering consumes mostly electrical energy, drying operation uses mostly thermal energy (by burning furnace oil).

There are many trucks and tractors used in the estates, which consume large quantities of diesel.

In addition to supplying electricity to factories, MM provides electricity to employees' homes.

MM uses some very old Ruston DG sets which at most places consume LDO.

At the four factories visited, energy meters were provided only at the substation and the electricity consumption in different processes is not monitored. Many important data related to energy consumption is not collected on a routine basis nor is it reported to the management periodically.

The TERI team felt that there was a significant scope for energy saving in all the factories visited.

As regards energy management at MM and its factories, the study tour indicated the following measures (tentative):

1. Formal energy management set-up at the Corporate office with qualified technical people

2. Energy management structure at the factories with existing staff members

3. Touring engineers made responsible for energy conservation efforts in a group of factories

4. Upgradation of existing equipment, insulation, etc. and introduction of new technologies for energy conservation

5. Modification to power distribution system

6. Instrumentation to enable monitoring and reporting of energy consumption

7. Detailed energy audits in each factory

8. Training and awareness programme

9. Water conservation

The training programme to be conducted by TERI in February 1990 would include all the above topics and more. The programme would be designed specifically to meet the needs of Mcneill and Magor.

G. Sambasivan

S. Anand

Electrical Energy Conservation

by
S. Anand

Introduction

The availability of an adequate amount of good quality electricity energy is essential for the industrial development of the country. Though there has been a phenomenal increase in the installed generation capacity during the past 40 years, the demand for power has outstripped the availability causing widespread shortages for power in different parts of the country.

The major brunt of this power supply shortage has been, and will be faced by the industrial sector which accounts for about 52 per cent of electricity consumed in the country. Besides having to live with poor quality and unpredictable supply of power, industries also have to cope with ever increasing energy prices. Recent events and future prospects for the demand and supply of electricity have underscored the necessity of giving conservation greater weight.

This requires efforts in two directions - maximizing energy efficiency in existing industrial units and adopting the most energy efficient technologies for future expansion and growth. A majority of industrial production today is based on processes, technologies and equipment designed and built when energy was cheap and readily available. As a result of this, there is large potential for energy conservation which has been estimated to be in the range of 20-30 per cent of the energy being used presently. These savings can be realized through energy conservation measures ranging from improved housekeeping practices to minor modifications in existing equipment to major equipment/process modifications.

Conservation practices in industry, however, will depend very heavily on the cost and availability of fuel/power and the motivation for implementing conservation schemes is influenced by a number of forces which relate to technical, economic and financial factors. In addition, institutional regulations and constraints are very often dominant factors.

Electrical Energy Use

At the tea factories, electricity is mainly used for providing motive power and for lighting. Of these, electricity used for motive power would alone account for about 95 per cent of the total electricity consumption.

Electrical energy consumption can be reduced by elimination or attenuation. Energy conservation schemes normally employ the latter method to reduce electricity consumption.

Electrical energy management can be effected by taking a variety of steps depending upon their suitability for a particular application.

1) Proper/optimal controls - use of simple timers, electronic/microprocessor based controls, variable speed drives for motors, etc. would provide better control over the process, which in turn could be used to optimize the functioning of equipment thereby reducing energy consumption;

2) Optimize Capacity - As far as possible, it is better to optimize capacity since excess capacity would result in under utilization which leads to inefficiencies;

3) Reduce Loads - As far as possible avoid loads which are non-essential to the production process;

4) Use more efficient processes - Technological changes have made possible the use of more efficient processes which are not only more effective, but also reduce energy consumption. For example, use of fluidized bed dryers;

5) Use more efficient equipment - Energy consumption can be reduced by using more efficient equipment, such as energy efficient motors, efficient lamps, etc.;

6) Employ special techniques - Use of power factor correction capacitors, resizing the distribution system, etc. would lead to further reductions in energy consumption;

7) Effectively contain energy and reduce losses - Installing heat recovery systems and better insulation are examples whereby energy could be contained and energy consumption reduced;

It is difficult to be exhaustive in reviewing various energy conservation schemes because of the diversity of processes, technologies and equipment, each having unique features and thus calling for unique energy conservation measures. This paper deals with some techniques for identifying potential for savings and for reducing electricity consumption in specific equipment like motors, lighting systems, and load management.

Electrical Energy Analysis

An electrical energy conservation programme requires:

- a systematic approach to electrical energy analysis;
- an investigation of all related systems which contribute to the consumption of electrical energy.

A systematic and detailed analysis of historical energy use data is essential to determine the energy use pattern. This analysis should be carried out at both the factory level as well as for specific equipment.

A systematic energy analysis entails carrying out a detailed energy balance to be made on each process, activity or facility, for a critical analysis of fuel use and identification of the potential for conservation. Such an analysis would help establish a bench mark or base line of energy use and energy use pattern. Based on this reference datum it could be determined where energy is being lost, and how much is being lost.

Effective measurement and monitoring procedures would be essential for such an evaluation. Energy meters would have to be installed not only at the mains but also at distribution boards within the plant and at specific equipment which are known to be major energy consuming centres. The composite factory load should be broken down into different sections such as withering, rolling/ cutting, drying, sorting and packing and within these sections, the motor load and the lighting load should also be considered separately to characterize electricity use in these systems. To be able to carry out such an exercise, it would also be necessary to ensure that the one distribution panel does not supply power to different sections of the plant.

The analysis should also include computation of the connected load, the maximum demand, the load factor - defined as the ratio of the average demand to the maximum demand, and the power factor. The variations in these during different periods of time and for different cycles of operation should also be accounted for.

Since the majority of the factories have similar layout, distribution and equipment, it should be possible to arrive at norms for specific electricty consumption which would apply to all the factories. Since seasonal variations have considerable effect on the green leaf quality the time required for withering etc., it would be important to arrive at norms for different times of the year. There would, however, still be some variations depending upon the mix of CTC and Orthodox tea production.

Electrical Load Management

Electrical load management is the process of scheduling load usage so as to reduce electricity use during peak load periods. Load management generally means increasing the electricity consumption during off-peak periods. The goal of a load management programme is to maintain, as nearly as possible, a constant level of load, thereby allowing the system load factor to approach 100 per cent.

The major benefit from load management is a reduction in the peak demand which would reduce the demand charges. It would also release a part of the system capacity for additional loads (in case of any expansion) to be placed on the system without the need for an additional transformer. Provided of course, that the additional load does not exceed the difference between the reduced peak load and the capacity of the existing transformer.

To conduct a load management programme, it is essential that the system load curve for the plant be defined to ascertain the peak load. Peaks may occur either due to system faults or due to improper management. Only by monitoring and analysing the load curve on a regular basis can the cause for peaks be ascertained. On the basis of this analysis, loads can be rescheduled to reduce the peaks. This would, offcourse, depend upon whether or not loads can be rescheduled and other operational constraints.

Load management would have far reaching benefits since a reduction in the peak load would be reflected not only in reduced demand charges but also in reduced line losses and consequently, improved voltage regulation and improved system efficiency.

At the Macneill and Magor tea estates, however, load management may not result in a significant monetary saving since the ASEB does not impose any demand charges.

Power Factor Correction

Power factor is defined as the ratio of real power (kW) to the apparent power (kVA) and is the cosine of the angle by which the current lags (or leads) the voltage. In case of inductive loads, the current lags the voltage and the power factor is 'lagging'; whereas in the case of capacitive loads, the current leads the voltage and the power factor is 'leading'.

At the tea factories, motors and lighting constitute the electric load and therefore, the entire load is inductive in nature. The overall power factor of the factory would be lagging. Poor power factor results in increased reactive current which leads to increased total current draw.

The total current is the vector sum of the reactive and working components of the current as given by:

$$I_T = \sqrt{(I_W)^2 + (I_m)^2}$$

where I_T is the total current, I_W is the working component of the total current and I_m is the magnetizing component. With an increase in the total current draw, the I^2R losses in the line increase which also results in greater voltage drop across the line leading to poor voltage regulation. Poor power factor also results in increased reactive power which leads to increased kVA demand which is apparent from the relation :

$$kVA = \sqrt{(kW)^2 + (kVAR)^2}$$

where kVA is the apparent power, kW is the real component and kVAR the reactive component of power.

Poor power factor can be corrected by either using shunt capacitors or by using sychronous motors which can be operated at leading power factor to compensate for loads with lagging power factor. At the tea estates, the use of shunt capacitors is most suitable for power factor correction.

Capacitors take leading current and thus compensate for the lagging current drawn by the load. To determine the rating of capacitor required for a particular load, it is necessary to determine the reactive power of the load.

The capacitor rating required to improve the power factor from an existing value to a desired value can be computed using the relation:

$$CkVAR = kW \times (\tan {}_1 - \tan {}_2)$$

where, CkVAR = capacitor kVAR required

kW = load in kW

$_1$ = COS^{-1} (existing power factor)

$_2$ = COS^{-1} (desired power factor)

Alternatively, power factor correction tables may be used to determine the rating of capacitor required to improve the power factor from an existing value to a desired value. Table 1 gives the kW multipliers for determining the capacitor kilovars required for power factor improvement.

Table 1

KW Multipliers for Determining the Capacitor Kilovars Required for Power-factor Improvement

riginal power factor cos θ_1	Desired improved power factor, cos θ_2																				
	0.80	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.0
0.50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.440	1.481	1.529	1.589	1.732
0.51	0.937	0.962	0.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.687
0.52	0.893	0.919	0.945	0.971	0.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.643
0.53	0.850	0.876	0.902	0.928	0.954	0.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.600
0.54	0.809	0.835	0.861	0.887	0.913	0.939	0.966	0.992	1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.559
0.55	0.769	0.795	0.821	0.847	0.873	0.899	0.926	0.952	0.979	1.007	1.035	1.063	1.093	1.124	1.156	1.190	1.227	1.268	1.316	1.376	1.519
0.56	0.730	0.756	0.782	0.808	0.834	0.860	0.887	0.913	0.940	0.968	0.996	1.024	1.054	1.085	1.117	1.151	1.188	1.229	1.277	1.337	1.480
0.57	0.692	0.718	0.744	0.770	0.796	0.822	0.849	0.875	0.902	0.930	0.958	0.986	1.016	1.047	1.079	1.113	1.150	1.191	1.239	1.299	1.442
0.58	0.655	0.681	0.707	0.733	0.759	0.785	0.812	0.838	0.865	0.893	0.921	0.949	0.979	1.010	1.042	1.076	1.113	1.154	1.202	1.262	1.405
0.59	0.619	0.645	0.671	0.697	0.723	0.749	0.776	0.802	0.829	0.857	0.885	0.913	0.943	0.974	1.006	1.040	1.077	1.118	1.166	1.226	1.369
0.60	0.583	0.609	0.635	0.661	0.687	0.713	0.740	0.766	0.793	0.821	0.849	0.877	0.907	0.938	0.970	1.004	1.041	1.082	1.130	1.190	1.333
0.61	0.549	0.575	0.601	0.627	0.653	0.679	0.706	0.732	0.759	0.787	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.156	1.299
0.62	0.516	0.542	0.568	0.594	0.620	0.646	0.673	0.699	0.726	0.754	0.782	0.810	0.840	0.871	0.903	0.937	0.974	1.015	1.063	1.123	1.266
0.63	0.483	0.509	0.535	0.561	0.587	0.613	0.640	0.666	0.693	0.721	0.749	0.777	0.807	0.838	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.474	0.503	0.529	0.555	0.581	0.608	0.634	0.661	0.689	0.717	0.745	0.775	0.806	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.419	0.445	0.471	0.497	0.523	0.549	0.576	0.602	0.629	0.657	0.685	0.713	0.743	0.774	0.806	0.840	0.877	0.918	0.966	1.026	1.169
0.66	0.388	0.414	0.440	0.466	0.492	0.518	0.545	0.571	0.598	0.626	0.654	0.682	0.712	0.743	0.775	0.809	0.846	0.887	0.935	0.995	1.138
0.67	0.358	0.384	0.410	0.436	0.462	0.488	0.515	0.541	0.568	0.596	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.965	1.108
0.68	0.328	0.354	0.380	0.406	0.432	0.458	0.485	0.511	0.538	0.566	0.594	0.622	0.652	0.683	0.715	0.749	0.786	0.827	0.875	0.935	1.078
0.69	0.299	0.325	0.351	0.377	0.403	0.429	0.456	0.482	0.509	0.537	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.906	1.049
0.70	0.270	0.296	0.322	0.348	0.374	0.400	0.427	0.453	0.480	0.508	0.536	0.564	0.594	0.625	0.657	0.691	0.728	0.769	0.817	0.877	1.020
0.71	0.242	0.268	0.294	0.320	0.346	0.372	0.399	0.425	0.452	0.480	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.214	0.240	0.266	0.292	0.318	0.344	0.371	0.397	0.424	0.452	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.186	0.212	0.238	0.264	0.290	0.316	0.343	0.369	0.396	0.424	0.452	0.480	0.510	0.541	0.573	0.607	0.644	0.685	0.733	0.793	0.936
0.74	0.159	0.185	0.211	0.237	0.263	0.289	0.316	0.342	0.369	0.397	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.132	0.158	0.184	0.210	0.236	0.262	0.289	0.315	0.342	0.370	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.105	0.131	0.157	0.183	0.209	0.235	0.262	0.288	0.315	0.343	0.371	0.399	0.429	0.460	0.492	0.526	0.563	0.604	0.652	0.712	0.855
0.77	0.079	0.105	0.131	0.157	0.183	0.209	0.236	0.262	0.289	0.317	0.345	0.373	0.403	0.434	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.052	0.078	0.104	0.130	0.156	0.182	0.209	0.235	0.262	0.290	0.318	0.346	0.376	0.407	0.439	0.473	0.510	0.551	0.599	0.659	0.802
0.79	0.026	0.052	0.078	0.104	0.130	0.156	0.183	0.209	0.236	0.264	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.633	0.776
0.80	0.000	0.026	0.052	0.078	0.104	0.130	0.157	0.183	0.210	0.238	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.609	0.750
0.81	.....	0.000	0.026	0.052	0.078	0.104	0.131	0.157	0.184	0.212	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82	.....	.....	0.000	0.026	0.052	0.078	0.105	0.131	0.158	0.186	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.555	0.698
0.83	.....	.....	.....	0.000	0.026	0.052	0.079	0.105	0.132	0.160	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.529	0.672
0.84	.....	.....	.....	.....	0.000	0.026	0.053	0.079	0.106	0.134	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85	.....	.....	.....	.....	.....	0.000	0.027	0.053	0.080	0.108	0.136	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86	.....	.....	.....	.....	.....	.....	0.000	0.026	0.053	0.081	0.109	0.137	0.167	0.198	0.230	0.264	0.301	0.342	0.390	0.450	0.593
0.87	.....	.....	.....	.....	.....	.....	.....	0.000	0.027	0.055	0.083	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.028	0.056	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.028	0.056	0.086	0.117	0.149	0.183	0.220	0.261	0.309	0.369	0.512
0.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.028	0.058	0.089	0.121	0.155	0.192	0.233	0.281	0.341	0.484
0.91	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.030	0.061	0.093	0.127	0.164	0.205	0.253	0.313	0.456
0.92	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.031	0.063	0.097	0.134	0.175	0.223	0.283	0.426
0.93	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.032	0.066	0.103	0.144	0.192	0.252	0.395
0.94	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.034	0.071	0.112	0.160	0.220	0.363
0.95	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.037	0.079	0.126	0.186	0.329
0.96	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.041	0.089	0.149	0.292
0.97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.048	0.108	0.251
0.98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.060	0.203
0.99	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.000	0.143
																					0.000

EXAMPLE. Find the ckvar to improve the power factor of a 500-kw load from 0.7 to 0.95

ckvar = kw × multiplier
= 500 × 0.691
= 345.5

Capacitors may be installed at either the substation, at distribution boards, at individual loads or, may be provided at all these locations to improve power factor at different stages and avoid the high cost of installing low rating capacitors. Ideally, capacitors should be connected as near to the load as possible to get the maximum benefit, since improvements due to capacitors are reflected backwards from the point of installation to the generators. Therefore by providing capacitors only at the substation, the industry would avoid the penalty for poor power factor but would lose out on other benefits such as reduced line losses, reduced loading of cables, improved voltage regulation and increased system efficiency. However, since ASEB does not levy any demand charges, it may not be economical to install capacitors at individual load points.

In installing capacitors, however, care should be taken that the capacitor rating is properly selected. Over-compensation is equally harmful and may also give rise to excessive voltage build-up when the motor is switched-off. In case of capacitor compensation for motors, it should be ensured that the capacitor current is not greater than the no-load current of the motor or, the capacitor kVAR is not greater than about 90 per cent of the no-load kVAR of the motor. Similarly, when connecting capacitors at distribution panels it should be ensured that loads are not switched-off with all capacitors connected in circuit.

In addition to the savings that are evident, there are other savings which are more difficult to quantify. For example, improved voltage regulation results in better operation of other equipment leading to an overall increase in system efficiency. In the final analysis, however, the installation of capacitors is influenced by the tariff structure, the cost, and the savings that could be achieved.

Lighting

Electricity consumed in the lighting system would vary from a small fraction to about 5 per cent of the total electricity consumption. In absolute terms, however, it might form a substantial quantity. With proper design and selection of lamps, substantial savings in electricity consumption could be achieved. Good lighting, however, is influenced by many factors which include physiological and psychological factors. Though it would be difficult to deal with all the factors which influence good lighting and visual performance, some of the important considerations which have to be borne in mind when deciding on a new lighting system or when considering a change, are dealt with in this section.

Human vision is not equally sensitive to all parts of the visible spectrum. The peak sensitivity of the human photopic vision (used in bright illumination) occurs at the wavelength of 555 nm. At higher and lower wavelength the sensitivity (technically known as spectral luminous efficiency) decreases. The response for wavelength less than 380 nm and greater the 760 nm is negligibly small.

Two measures of visibility are 1) minimum perceptible contrast, and 2) visual acuity

Minimum perceptible contrast is the minimum perceptible difference in luminance that can be perceived between a small dot and its surroundings. For low background luminance, increasing lighting levels decreases the minimum perceptible contrast. However, at high luminiance levels increasing the background luminance has little benefit.

It might therefore be less expensive and more effective to redesign the task to improve its contrast than to increase illumination. For example, using white paper instead of coloured paper in an office would improve contrast thus producing less strain while reading. It is important to realize that the illumination required is determined by task contrast.

Visual acuity is the measure of the ability to perceive detail. Here again, beyond a certain limit, redesigning the task is more beneficial than increasing the illumination. Another factor which affects visual performance is veiling reflections.

Veiling reflections are a form of reflected glare where the task surface acts as a mirror, reflecting light directly into the eyes of the observer. Veiling reflections decrease task contrast, but their effect is milder than disability glare. Veiling reflections can be avoided by proper placement of light fixtures. For example, placing the light source behind or above a person seated at a desk is better than placing it in front of the person.

Selecting the most suitable lamp for an application is of the utmost importance. Now-a-days, incandescent lamps are rarely used in industries and lighting is generally provided by fluorescent lamps. Mercury vapour and high pressure sodium vapour lamps are also increasingly being used in industry.

The efficacy of a lamp is defined by the ratio of the lumen output to the lamp wattage. The efficacy of different lamp sources are given in Table 2. The colour rendering characteristics of different lamps is given in

Table 3. It can be seen from these tables that high pressure sodium vapour lamps are amongst the most efficient light sources. Though its colour rendition is not as good as that of fluorescent lamps, it can be effectively used in most factory areas. It is, however, not suitable for areas where good colour rendition is required.

Table 2

Efficacies of Different Type & Wattages of Lamps

Type of Lamp	Efficacy (Lumens/Watt)
GLS Incandescent (25W to 1000W)	8 - 18
Tungsten Halogen (300W to 1000W)	22 - 27
TLD Fluorescent (18W, 36W, 58W)	61 - 72
TL Fluorescent (20W, 40W, 65W)	55 - 65
High Pressure Mercury Vapour (HPLN) (80W, 125W, 250W, 400W, 1000W)	40 - 57
High Pressure Sodium Vapour (SON, SON-T) (70W, 150W, 250W, 400W)	82 - 120
Low Pressure Sodium Vapour (SOX)	100 - 140
PL (9W, 11W)	60 - 70

Proper lighting design has to take into account various factors such as:

- Area of the work place
- Type of activity to be performed
- Type of lamp best suited to provide the desired illumination
- Type of luminiare to be used
- Mounting height of lamps
- Lighting arrangement/distribution
- Switching arrangement
- Colour/reflectance of walls, ceiling and floor
- Use of daylighting
- Colour rendition required
- Average age of persons working in the area

TABLE 3
Light Sources and Their Characteristics
A Guide for Lamp Selection Based on General Color Rendering Properties

Type of Lamp	Efficacy (lpw)	Lamp Appearance Effect on Neutral Surfaces	Effect on "Atmosphere"	Colors Strengthened	Colors Grayed	Effect on Complexions	Remarks
Fluorescent Lamps							
Cool[a] white CW	High	White	Neutral to moderately cool	Orange, yellow, blue	Red	Pale pink	Blends with natural daylight—good color acceptance
Deluxe[a] cool white CWX	Medium	White	Neutral to moderately cool	All nearly equal	None appreciably	Most natural	Best overall color rendition, simulates natural daylight
Warm[b] White WW	High	Yellowish white	Warm	Orange, yellow	Red, green, blue	Sallow	Blends with incandescent light—poor color acceptance
Deluxe[b] warm white WWX	Medium	Yellowish white	Warm	Red, orange, yellow, green	Blue	Ruddy	Good color renditions simulates incandescent light
Daylight	Medium-high	Bluish white	Very cool	Green, blue	Red, orange	Grayed	Usually replaceable with CW
White	High	Pale yellowish white	Moderately warm	Orange, yellow	Red, green blue	Pale	Usually replaceable with CW or WW
Soft white/ natural	Medium	Purplish white	Warm pinkish	Red, orange	Green, blue	Ruddy pink	Tinted source usually replaceable with CWX OR WWX
incandescent Lamps, Tungsten Halogen							
Incandescent filament	Low	Yellowish white	Warm	Red, orange, yellow	Blue	Ruddiest	Good color rendering
High—Intensity Discharge Lamps							
Clear mercury	Medium	Greenish blue-white	Very cool, greenish	Yellow, blue, green	Red, orange	Greenish	Very poor color rendering
White mercury	Medium	Greenish white	Moderately cool, greenish	Yellow, green, blue	Red, orange	Very pale	Moderate color rendering
Deluxe white[a] mercury	Medium	Purplish white	Warm, purplish	Red, blue, yellow	Green	Ruddy	Color acceptance similar to CW fluorescent
Metal halide[a]	High	Greenish white	Moderately cool, greenish	Yellow, green, blue	Red	Grayed	Color acceptance similar to CW fluorescent
High-pressure Sodium[a]	High	Yellowish	Warm, Yellowish	Yellow green	Red, blue	Yellowish	Color acceptance approaches that of WW fluorescent

Source Courtesy of General Electric Co., Lamp Division.

[a] Greater preference at higher levels

[b] Greater preference at lower levels

The activity to be performed, the colour rendition required and the illumination to be provided at the task determine the light source which is most suitable. The general tendency is to provide uniform light levels at all locations which in turn would be determined by the illumination required for the most difficult task to be performed. This results in unnecessary wastage of electricity. Non-uniform lighting can be the key for providing good illumination. However, it should be ensured that it does not create sharp contrasts.

Task lighting is one of the most effective ways of providing acceptable levels of illumination at the work place. Background lighting however, has to be provided to ensure visibility even when task lights are turned off. Task lighting provides considerable potential for electricity savings since lamps can be selectively switched off. For office areas, however, uniform lighting is more suitable.

To provide proper lighting it is also important to select the right luminaire and mount it at the right height. The most efficient lamps would not provide proper illumination if used with a badly designed luminaire. Similarly, by mounting the fixture at a height greater than, or very much lower than that specified by lamp manufacturers would result in inadequate lighting.

Provision of proper switching arrangement is perhaps the single most effective way of reducing electricity consumption in lighting. Switching arrangement should be provided such that lamps can be selectively switched off when not required. An effective means of reducing lighting electricity consumption would be to provide separate switches for lamps along windows so that they may be switched off when there is adequate daylighting. Daylighting can be improved by providing skylights and transluscent fibre reinforced plastic (FRP) sheets on the ceiling.

All efforts at providing good lighting can be negated with inadequate maintenance of the lighting system. It is important that lamps and luminaires are cleaned at periodic intervals to ensure that fixtures provide the illumination levels they were designed for. However, over a period of time the lumen output from lamps depreciates and it is advisable to replace lamps at the end of their economic life (defined as the time by which lamp lumen output reduces to about 70-75 per cent of the design value). Group relamping programmes are most suitable to ensure uniformity of illumination from multi-lamp fixtures.

Even in existing lighting system, electricity consumption can be reduced in a number of ways. Using slim tubelights and electronic ballasts is one way of reducing electricity consumed in fluorescent lamps. A summary of measures by which lighting electricity consumption could be reduced in both new and existing systems is given below.

1. Design lighting for the task

2. Provide the required illumination for visual tasks in the working areas only, and appropriate lower levels in the general areas such as corridors, storage, and circulation areas.

3. Reduce the wattage required for each specific task by reviewing user needs and methods of providing illumination

4. Consider only the amount of illumination required for the specific task, taking into account the duration, the character, and the user performance required.

5. Consider use of greater contrast between tasks and background lighting.

6. Select the proper lighting systems

7. Use fixtures that give high contrast rendition at task

8. Keep exterior lighting to a minimum

   a. Eliminate exterior lighting except where used for identifying the building entrances and/or for security.

   b. Coordinate street lighting with security lighting and eliminate duplication

   c. Use high-efficiency light sources (high-pressure sodium or high-intensity-discharge lamps).

   d. Use efficient luminaires (prismatically controlled lens, rather than general diffusion or decorative geometric forms).

   e. Use photocells for turning on exterior lights, and time clocks for turning them off.

9. Select the most efficient luminaires.

10. Consider the use of high-frequency electronic ballast to reduce wattage per lumen output. (Additional benefits are reduced ballast heat loss and longer lamp life).

11. Select the most efficient light sources.

12. Consider the use of light colours for walls, floors, and ceilings to increase reflectance (but avoid specular reflections)

13. Lower ceiling or mounting height of luminaires to increase the level of illumination with less wattage.

14. Select furniture and interior appointments that do not have glassy surfaces or give specular reflections

15. Use high-reflectance finishes on room surfaces (particularly vertical surfaces).

16. Lay out the luminaires for visual performance rather than uniform space geometry.

17. Within the limits of the luminaire supporting system, locate the luminaire as close to or, directly over the task, as possible without creating excessive reflections.

18. Avoid locating luminaires directly in front of the visual task.

19. In multiple-task areas luminaires should be located between the desks so that the main lighting components originate from either or both sides of the desk.

20. Luminaires should be selectively switched according to possible grouping of working tasks at different working hours.

21. Design switch circuits to permit turning off unused or or unnecessary lights.

22. Provide timers to automatically turn off lights in remote or seldom used areas.

23. Utilize daylight

The key element in a lighting management programme appears to be the perception of the workers that the management is attempting to improve the working conditons.

This perception can occur by repainting equipment, decorating walls, improving the distribution of lighting, and so on. In essence, management´s show of concern for the employees appears to be the determining variable.

Removing light fixtures to save money can often be interpreted as taking something away from the workers and can decrease productivity simply by affecting workers' morale. In fact, the problem of optimizing lighting to save energy is usually quite closely tied with the problem of relationship between the workers and the management.

A successful programme for improving energy efficiency in lighting must pay considerable attention to the perception by the workers of the management, of the energy efficiency programmes and its recommended changes.

Motors

Electric motors account for nearly 95 per cent of the total electricity consumption of the factories and provide considerable potential for energy conservation.

Motor electricity consumption can be reduced by operational improvements such as operation as balanced and rated voltage, regular maintenance, provision of adequate cooling, etc; and by retrofit improvements which include power factor correction, proper selection of motor rating, use of energy efficient motors and variable speed drives.

Please refer to the paper entitled 'Electrical Energy Conservation in motors' for a more detailed discussion on the operation of motors and energy conservation opportunities in electric motors.

Withering

In tea processing, withering is one of the most energy intensive operations accounting for about 25 per cent of the total factory load. Savings could be achieved in the withering process by using dual/multi speed motors. Over a period of time as the leaf gets withered, the fan motors could be switched over to a lower speed thereby reducing energy consumption. Savings could also be achieved by switching off the fans for short durations of time in between the withering process. The duration over which the fan could be switched off would have to be determined experimentally by a trial and error method. The time duration would also have to be changed depending upon seasonal variations. It would be required to carry out a careful study to determine the possibility of shutting off fans used in withering troughs. It should also be ensured that there is no air leakage from the sides of the troughs. To obtain a uniform wither, it would be required to have a slight paper in spreading the leaf over the trough, so that the end nearer to the fans is thicker than the opposite end. This especially significant since the withering crops used at the Macneill and Magor tea factories are very long.

Fermentation

In the fermentation process, it was observed that often the fermentation trough fans were on even when the troughs were empty. Here too, the possibility of using of dual speed motors should be examined. This would have to be done in conjunction with the provision of dampers at the air-duct entry point to each trough. Such an arrangement would make it possible to close the dampers of troughs not in operation and run the fan at a lower speed. It is also recommended that the use of a spring loaded mechanism be considered by means of which the air ducts of each individual trough could be closed in the absence of the fermenting tray. Although the fermentation load forms a very small percentage of the total factory load, in absolute terms the savings would be significant.

The air supplied to the fermenting troughs is humidified by spraying water at the suction end of the fermenting trough fan. In this process a lot of water is drained and fresh water is pumped in. Since energy has been spent in supplying water, it is essential it be used with care and to the fullest extent. It is therefore recommended that a sump be constructed so that the water required for humidification of air is recycled. The pump presently being used could itself be used for recirculating the water. A mechanical float valve could be used to replenish water to the sump.

At Pertapghur tea estate, it was observed that one of the overhead tanks was overflowing. It is recommended that simple mechanical water level detecting devices be installed so that the motor is switched off when the tank is full.

Electrical Distribution System

At the Macneill and Magor tea estates, electricity is supplied by the ASEB. In addition, DG sets are used during power cuts. Presently, the DG sets are not synchronised and different distribution boards are supplied from separate DG sets depending upon the load and the capacity of the DG sets. Such an arrangement is inefficient since it leads to under utilisation of the DG sets when the load at the distribution board reduces. It is recommended that the DG sets be synchronised (as at the Monabarie tea estate) or a suitable arrangement be devised so that the DG sets are optimally loaded. Such a measure would result in significant savings in diesel oil consumption.

Instrumentation and Monitoring

Instrumentation is vital to the actual measurement of energy flows and in determining energy efficiencies. Adequate instrumentation should be provided at different sections of the factory and feeder distribution points. This would enable monitoring of energy flow in different equipment and help in recording the energy usage pattern. Such information would be also be helpful in conducting energy audits on a regular basis.

However, it must be noted that instruments remain accurate only if they are adequately maintained and regularly caliberated. Without proper instruments to measure energy flows, energy conservation measures will be difficult to conceive, design and implement.

Operation and Maintenance

In most industrial operations embarking on an energy management programme, the immediate savings in energy utilization can be achieved by minor improvements in the operation and, above all, through the implementation of an effective maintenance programme.

Maintenance efforts, traditionally have been motivated primarily by the concern for preserving equipment. Energy use has not been given due consideration. However, the increasing costs of electricity dictate that this deficit be remedied. Maintenance programmes can provide the framework for organized reduction in energy-consumption. Normally, maintenance could be preventive or corrective. **Preventive maintenance** has scheduled down-times for routine cleaning, repairs, etc. In **breakdown maintenance,** equipment is operated for extended periods of time with maintenance called for only when equipment shows clear signs of impending malfunction. The latter approach wastes energy, because equipment is operating at reduced efficiency for part of the time.

Maintenance could also be predictive. **Predictive Maintenance** skirts both these pitfalls; it slashes costs and saves energy. The approach requires taking key measurements, along with a sure knowledge of how the equipment should be operating for the conditions existing. In essence, it is very simple; the process is carefully monitored; when performance begins to tail off, the deterioration is recognised and probable reasons pin-pointed. Maintenance is then needed, but it can be scheduled in between the extremes of routine and contingency conditions.

A proper combination of preventive maintenance, predictive maintenance and corrective maintenance, and cleaning and inspection of equipment can effect significant energy savings.

ENERGY EFFICIENCY IN TRANSPORT VEHICLES[*]

Introduction

This paper examines the most effective ways of cutting down fuel waste in road vehicles. In many cases little or no cost is involved, the saving being achieved by greater attention to such factors as:

- monitoring vehicle and driver performance
- reducing aerodynamic drag losses
- reducing engine and transmission losses
- tyre management
- maintenance[**]
- improved operational planning

Energy efficiency in road transport means saving fuel, and as fuel accounts for a substantial portion of the overall operating cost of a vehicle, the potential for saving energy and therefore, money can be appreciated.

Assessing Current Performance

Surprisingly perhaps, many operators (factories) have only a rough idea of fuel consumption of their vehicles; which means that not only is it impossible to measure any improvements resulting from an energy efficiency programme, but also, where there is a 'rogue' vehicle in the fleet, it is often some time before its poor performance is noticed.

It is therefore essential to establish a datum to which any improvement in fuel consumption may be related. Whereas with a house or factory it is possible to estimate the likely energy costs (heating, lighting and so on) based purely on the size and construction of the building, no such generalization is possible with a fuel consumption of a commercial vehicle, because there are too many variables. Type of body, type of operation, type of loading pattern - all of these have a considerable influence on the fuel consumption. It follows therefore, that an accurate assessment of the fuel used is essential if any efficiency improvement programme is to be implemented. At the tea estates, the tank-to-tank topping up method could be used at the end of the journey/day. This would require an estimation of distance travelled every day or in a trip by a vehicle, if there is no odometer. The tank-to-tank system of evaluation can be of value only if it is carried out properly.

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[*] Adapted from 'Energy Efficiency in Road Transport' Fuel Efficiency, Booklet No.20, Energy Efficiency Office, U.K. 1987.

[**] See Appendix for an example of maintenance schedule at the Pertabghur Estate.

Many fuel tank designs make the elimination of air pockets during a filling a tedious process and it is often difficult to know when a tank is full. This immediately implies a potential source of inaccuracy; so to minimize this, the driver should be asked to put in fixed number of gallons at the end of each shift without actually filling the tank to the brim. At the end of, say, a week, the tank should be topped up under supervision, and so in this way, any error due to uncertainty over whether the tank is completely full will be restricted to one error per week instead of the cumulative effect of one per day.

Weather is one of variables which would affect fuel consumption of a vehicle. It is easy to be misled into thinking that an improvement in consumption has been achieved when the `before' test was carried out on a wet day and `after' test was done in the dry. Tyre drag increases when the roads are wet, and so the apparent improvement in fuel consumption could be due entirely to the weather.

It is essential when analyzing the performance of a vehicle that all the variables are kept under control. As well as the weather, other variables include the route, the gross weight and the height of the body or load. It hardly seems necessary to point out that a different gross weight for example will give a different fuel consumption.

The message here is quite straightforward. It is essential to monitor the fuel consumption of a vehicle, but great care is needed to interpret results correctly.

Driver Involvement

The diesel engine in a modern commercial vehicle (including tractor) has different performance characteristics from its predecessor of just a few years ago. In a large vehicle a 250 to 270 -hp engine of the mid-seventies produced its maximum power at engine speeds of up to 2600 rpm, whereas its equivalent of the eighties usually runs no faster than 1900 rpm - for the same rated output.

The lower the engine speed, the lower the interal friction within the engine - one of the factors which has helped to achieve the improvements in consumption apparent with modern designs. However, it is obvious that these lower engine speeds must be adhered to or the benefits will be lost. And this is where `driver familiarization' comes in.

Making the driver want to save fuel is a major factor in any energy efficiency program, and hence, it is vital to use a little tact here. Many drivers will resent any implication that their driving can be improved, but if it can be demonstrated that they can save fuel with no increase in journey time, resentment will usually disappear.

One factor associated with modern low rev/high torque engines is that they require less gear changing and thus less of driver's effort, because the engines will still `pull' strongly at speeds as low as 900-1000 rpm. But the driver has to be told what the characteristics of the engine are before any benefit in technology can be translated into economy.

The Petroleum Conservation Research Association (PCRA) offers free training programmes for drivers. To benefit from this service, it is recommended that Macneill and Magor contacts a PCRA office in Assam, or write to Chief Executive Director, Petroleum Conservation Research Association, 1008 New Delhi House, Barakhamba Road, New Delhi 110 001.

Driver Motivation

The attitude to fuel usage is often mirrored by the differences in tyre wear and maintenance costs of a vehicle. It is therefore important to monitor both vehicle and driver performance to ensure that the poor performance can be identified and suitable action taken.

As a way of encouraging the driver to become involved in an energy efficiency scheme, some form of incentive scheme can be devised. This can take the form of a financial bonus related to savings achieved, or something more light-hearted like an economy `league table'. It is admitted that few companies have managed to operate a bonus scheme successfully for a variety of reasons, but with the league table it is a different matter. Drivers tend to be competitive over their skills and a list pinned up is a common area showing the economy achieved by the drivers the week before can pay dividends.

Vehicle Operation

i) Engine Losses

Engines are at most efficient at higher temperatures, which means running with the coolant just below its boiling point. It follows that accurate control of air flow through the radiator and over the engine is extremely important. As a rule of thumb, fuel consumption increases by approximately one per cent for every 6°C below optimum engine temperature.

Improved Lubricating Oils

These are continually coming on to the market. The improved engine oils aim to reduce fuel consumption by reducing the oil viscosity, and adding friction modifiers to maintain protection against wear of the moving parts. Abroad (in the U.K.), with the use of improved lubricating oils, fuel savings of about 2 per cent have been measured in dynamometer tests on diesel engines, rising to 4 per cent on small petrol engines.

Fuel Additives

It has been argued that a turbocharged diesel engine on a highway needs a different fuel to that required by a naturally aspirated engine involved in urban areas. This has led to the appearance of many fuel additives on the market which are claimed to improve fuel consumption-usually by reducing the surface tension of the fuel droplets leading to better atomization and improved combustion.

In spite of the claims put forward by the manufacturers, few, if any, additives have been shown to give an improvement in fuel consumption under normal operating conditions. One difficulty is that the claimed improvements are often less than 4 per cent, which is extremely difficult to measure anyway.

This should not be seen as an attempt to decry the use of additives in principle. It is just that operator experience to date with additives currently available suggests that the claimed improvements in fuel consumption are not justified by the results.

ii) Reducing Transmission Losses

Information on the losses of transmission systems is somewhat limited. A single drive axle will usually have an efficiency of more than 90 per cent and so there is not a lot of scope for improvement. Losses wil be highest when a 'thick' oil is being used and the temperature is low, and under these conditions an improved lubricating oil could lead to significant fuel savings. It would be advisable before changing to a new type of oil (if one is available) to check with the oil company and with the vehicle or engine manufacturer that the proposed change meets with their approval.

Gearboxes are very efficient mechanisms when operating in direct drive and so there is no much room for improvement. In intermediate gears, however, efficiencies are not so high and it is possible that a low viscosity oil could lead to increased efficiency.

The vast range of vehicles, engines, and transmissions makes it impossibe to quote an average figure for fuel saving in the transmission; the maximum saving that could be obtained by changing to a more efficient axle and using a low viscosity lubricating oil would be about 5 per cent. Check with authorized oil supplier or PCRA and vehicle manufacturer before changing to a low viscosity oil.

iii) Routing and Scheduling

The less miles a vehicle covers, the less fuel it will use. In practical terms this means that fuel savings may be generated by planning vehicle operations to carry out the work required while covering the minimum mileage.

Where the operation requires the movement of complete vehicle loads to a single destination, it is necessary to select the best and shortest destination, or quickest practical route. For most journeys, there are a number of possible routes which could be taken. Choice of the 'incorrect' route will often result in the use of more fuel than is necessary. For short distances for which a vehicle is not required, one should either walk or use a bicycle to save energy.

iv) Maintenance

Effective vehicle maintenance systems* are essential, not only for smooth operation, safety and vehicle reliability, but also for good fuel efficiency. A badly maintained vehicle will almost certainly use more fuel than is necessary.

Every maintenance system needs to be built around frequent and efficient arrangement to monitor the condition of each vehicle:

- every driver should be required to check his vehicle daily and be trained to recognize and report on fuel-related faults;

- every vehicle should be regularly examined by a qualified inspector, and again, as part of this inspection, fuel-related faults should be identified.

Everyone involved in vehicle maintenance, and that includes drivers, vehicle inspectors and mechanics, must have an awareness of fuel-related faults such as black exhaust smoke, fuel leakages, incorrect tyre pressures, binding brakes and so on. Managers have the responsibility of ensuring that the maintenance staff is aware of the amount of fuel that can be wasted by such faults and the maintenance systems should be such that corrective action can be taken rapidly to rectify them.

The following fuel-related faults are very common on commercial vehicles:

1. Fuel leaks (supply) – fuel tanks, fuel pipes, connectors, filters, lift pumps

2. Fuel leaks (injection) – high prerssure pipes & connections, injection pumps, injectors

3. Engine – black smoke, performance, throttle faults, fast stick over

4. Tyres – misalignment and scrub, low pressure

5. Brakes – binding

6. Clutch – slip, bad adjustment

Unless there is:

- an awareness of the effects of fuel-related faults;

- a conscious effort to closely monitor vehicle condition by drivers, inspectors and mechanics;

- a maintenance system to rapidly rectify such faults, fuel will be wasted

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* It has been noticed by the energy study team from TERI that at Pertabghur, all the tractors, cars and gypsy were regularly maintained every two weeks.Such routine maintenance would ensure higher energy efficiency.

v) Vehicle Weight Reduction

If the weight of a vehicle is reduced by suitable changes in material, the fuel consumption would reduce. Macneill and Magor should examine if the weight of trailers could be reduced by using light weight aluminium instead of steel in the racks.

vi) Management Controls

Earlier in this paper it was emphasized how important it was to have a reference point for fuel consumption before any form of energy efficiency programme can be attempted.

Following on from this, ongoing monitoring is needed to ensure that any subsequent improvements are maintained under everyday operating conditions.

If there is a bulk fuel tank within the factory premises, issues of fuel need to be recorded both for accountability and for fuel efficiency reasons. For the smaller user (where applicable), manual recording of fuel issued-either by the driver or other designated person - may be the only solution, but this is rarely wholly satisfactory.

Conclusion

This paper examined the various ways (which are applicable in Macneill and Magor tea estates) in which the fuel consumption of commercial vehicles can be improved. Checklists for vehicles and their operation for fuel efficiency are given below.

Fuel Efficiency Checklist for Vehicles:

- Are the tyres in good condition and at the correct pressures ?
- Are the wheels correctly aligned ?
- Is the fuel system free from leaks ?
- Is the fuel system adjusted to the manufacturer's recommendations ?
- Are the air cleaners serviceable ?
- Is there any evidence of brakes binding ?
- Is there any evidence of clutch slip ?

Fuel Efficiency Checklist for Operation:

- Are the speedlimits being observed ?
- Is the engine stopped when parked or unloading/loading ?
- Are fuel purchases from outside sources kept to a minimum ?
- Is advantage being taken of the various fuel economy aids which are available ?
- Is the fuel consumption of the vehicle(s) monitored accurately ?
- Are the routing and scheduling arrangements designed to help fuel economy ?
- Are the drivers instructed in the optimum driving techniques for the vehicles in question ?

-- * --

APPENDIX

Pertabghur

Tractor Maintenance Schedule

1st and 3rd Monday and Wednesday – No. 1 Tractor
1st and 3rd Tuesday and Thursday – No. 3 Tractor
1st and 3rd Wednesday and Friday – No. 4 Tractor
1st and 3rd Thursday and Saturday – No. 5 Tractor
1st and 4th Friday and Monday – No. 6 Tractor
1st and 4th Saturday and Thursday – No. 7 Tractor
2nd and 4th Monday and Wednesday – No. 8 Tractor
2nd and 4th Tuesday and Thursday – No. 9 Tractor
2nd and 4th Wednesday and Friday – No.10 Tractor
2nd and 4th Thursday and Saturday – No.11 Tractor
2nd and 1st Friday and Monday – No.12 Tractor
2nd and 1st Saturday and Tuesday – No.13 Tractor
3rd and 1st Monday and Wednesday – No.13 Tractor
3rd and 1st Tuesday and Thursday – No.15 Tractor

Car Maintenance Schedule

1st and 3rd Monday : Mr. Sharma
Tuesday : Mr. Sandhu
Wednesday : Mr. ?
Thursday : Mr. Mishra
Friday : Mr. Rikhye
Saturday : Mr./Dr. Pandey

2nd and 4th Monday : Manager's car
Wednesday : Gypsy/Tata 407
Thursday : Matador
Friday : Mr. Pabnda
Saturday : Mr. T. Singh

ENERGY AUDIT

by

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Introduction

Energy is a vital input to industrial production and national economy. In 1987-88, India's total commercial energy use was 103.35 million tonnes of oil equivalent (Mtoe). A conservative energy saving of 10 per cent would have saved the nation more than 10 Mtoe. What would this saving mean to an industry or a commercial organization ? It could mean increased profits, more competitive pricing, and more money available to improve services to public. To the nation, it would mean less investment in energy supply industry, allocation of funds thus released for social programmes, and less impact on the environment from energy production and energy use.

A sound energy management programme in any organization would mean monitoring of energy consumption and energy flows at various locations, keeping a record of such measurements, and analyzing the data for improving the energy efficiency. This is in short known as **energy audit**.

In this paper, the principles of energy audit in an industrial unit are discussed with a view to provide the reader an introduction to energy audit. The fundamentals highlighted here can also be applied to commercial organizations.

What is an Energy Audit ?

Beginning in 1973, energy suddenly became a very important topic. It was elevated to the position of a major topic almost overnight when mass media, politicians, government, business and consumer advocates started talking about it. The need to use energy (especially oil) efficiently was felt more than ever before in 1973-74, after the first oil crisis.

Years before the first oil crisis, professionals realized the importance of cutting down on energy consumption, and developing and utilizing methods of using less energy to produce same or more quantity of any product. The incentive then, as now, was saving money on purchased fuel and electricity. Probably no one would ever know when the term 'energy audit' was coined. The term has certain negative implication and it is not very descriptive. The dictionary meaning of the word 'audit' is 'a formal examination and verification of financial accounts'. This description does not fully convey the meaning of energy audit. Hence, it would probably be better to use an alternative terminology to describe the energy activities mentioned in this article as 'plant energy study'. However, as the term energy audit has been used for many years by people who speak with authority in energy matters, the expression will stay with us for many more years.

Types of Energy Audit

Basically, there are two types of energy audit. They are known as:

(1) Preliminary Scoping Study, and
(2) Detailed Energy Audit

The types of energy audit relate essentially to the scope of energy study, as will be seen below.

Preliminary Scoping Study

The preliminary scoping study (or preliminary energy audit or walk-through energy audit) is used by the professional energy consultant to help define, for himself and for the prospective client, the true dimensions and character of the energy problem at a specific plant. Usually, a qualified consultant visits an industrial unit just for a day. From the data gathered during his visit and his survey of the actual plant, he is able to define the total energy involvement of the plant in energy and monetary terms, and point out areas where energy could be saved with little or no investment. The scoping study includes detailed discussions with plant people regarding past energy consumption trends and energy-saving schemes, as well as the energy management structure both at the plant and corporate levels.

After a few days of analysis of data gathered during the plant visit, the consultant presents the results of the study in a concise report. If he is convinced that significant energy savings would result if a detailed study of the energy consumption in the plant is made, the consultant recommends to the client a detailed energy audit. A proposal for such a service will usually accompany the scoping study report.

The basic objective of a scoping study is to define the energy problem. This can usually be done most effectively by an outside energy consultant. However, a similar technique should be also applied as a first step if meaningful in-house plant energy studies are contemplated.

In the case of factories of Macneill and Magor, it is recommended that an outside consultant(s) be employed to conduct preliminary energy audit in each factory for the first time. After sufficient expertise is developed within a factory, an energy audit could be done by the plant personnel.

Energy Bus. An energy bus is a van fitted with computers, measuring instruments, demonstration equipment including video units, and staffed by two engineers. The energy bus is primarily used to carry out on-the-spot energy audits of small- and medium-sized industrial units, and commercial establishments. The purpose of such audits is to propose short-term energy-saving measures. The energy audits would, on the average, take two days per plant.

The concept of energy bus originated in Canada in the late 1970s and was later adopted in 1980 by the European Economic Community. Currently two organizations in India, including TERI, have acquired energy buses to conduct preliminary energy audits.

Detailed Energy Audit

The detailed energy audit is a thorough analysis and evaluation of all aspects of energy procurement, storage, conversion, distribution and use within an industrial plant or an industrial complex. The effort is intended to define and develop all the significant measures that can be taken within practical limits to improve energy efficiency of the plant and reduce energy costs. A detailed or complete energy audit transcends traditional arbitrary organizational barriers to realize its full potential. The study can be conducted in-house, provided sufficient expertise is available. If external help is sought, it should never be considered as a substitute for internal effort, but rather as a supplement to the plant/factory or corporate energy management programme. In many instances, an outside consultant would be able to point out areas for improvement which a plant personnel would not have noticed due to oversight or neglect.

Quite often, special energy audits are conducted to identify areas for improvement with a narrower scope. These are conducted based on certain priorities assigned by the management as areas requiring special emphasis. Some examples of such audits are: (1) withering trough study, (2) drier audits (3) electrical energy audit (4) diesel generator study, and (5) transport fleet system study.

The danger with special energy studies, however, is that the area selected for study may not be the real problem, but only part of it. Enormous effort would often be spent in such studies in identifying symptoms rather than the cause of poor energy efficiency. Therefore, it is obvious that special energy audits if required should be pinpointed at the end of a complete energy audit, as part of recommendations.

Energy auditing is a continuing effort to maintain a level of saving and to improve further when opportunities are identified. One cannot rest on past laurels. Unless the momentum is maintained, it would be easy to slip into lower levels of energy efficiency. Therefore, it is important to continue energy studies in the tea factories where a detailed energy audit has been conducted. It is normally recommended that at six-month intervals, an evaluation of progress against the initial recommendations is made; also, new recommendations are developed that have been made viable as a result of changes in energy costs or availability, and changes in product-mix or process technology.

Factory energy studies should never be considered on a one-time basis. The successful conduct of detailed energy audit, in itself, is a substantial economic incentive for continued emphasis. It may be necessary to develop internal resources to continue the effort in this regard.

How to Start an Energy Audit

Development of a data base is a very valuable activity in the successful conduct of an energy audit. First, an attempt should be made to complete a table similar to Table 1 for fuel and energy used in a tea estate including the tea factory for the last financial year.

Table 1: Quantity of purchased energy used and its cost for the last financial year

Type of Energy	Units	Quantity Used	Mkcal or MJ	Cost per Unit of Energy	Total Cost
Liquid fuel	kL or tonne				
- T.D.Oil					
- H.S.D.O					
- L.D.O					
Gaseous fuel	M cu.m				
Purchased electricity	MkWh				
Other					
Total					
Self-generated electricity					

Having completed the table, one is now aware of what is the cost of energy in the last financial year, how much of it was used in total and by energy forms. A simple step like the one described above should be the beginning of an energy audit programme. The data would further be broken down by areas where energy is consumed, by equipment, by systems, etc. Even an inventory of energy consuming equipment (e.g., motors) with relevant energy data would be important in an energy audit. Specific energy consumption values, e.g., L.T.D. Oil/energy efficiency, mainly to set targets, identify reasons for variations and measures for correction.

In all tea factories, Assistant Managers could be made the focal point during the conduct of an energy audit. They would essentially carry out the responsibility as energy coordinators, in addition to other responsibilities. Factory Managers would be responsible for providing leadership in the plant's energy conservation effort, and assume the overall responsibility for energy conservation.

Energy is a vital management function and this must be recognized by the top management. The top management is responsible for ensuring that appropriate plant studies are conducted, that the needed resources are provided, and that satisfactory sustained results are achieved.

The other people resources would include advisors, touring engineers, head tea house babus (supervisors), operators, and others willing and capable to implement and sustain the final end actions that must be taken to save energy. As the worker and the supervisors are closest to the use of energy, it is not unusual for the most productive energy conservation ideas to come from this group. Their participation in an energy audit should be encouraged.

Outside energy consultants, equipment vendors, and engineering and design firms would also play a part in energy audit depending on the energy audit requirements and the recommendations stemming from the energy audit.

Instrumentation. Whether an energy audit is done with resources from within the organization or by an outside consultant, measuring and recording instruments would be needed. Both on-line and portable instruments are required depending on the quantity measured and the type of measurement. Proper and adequate instrumentation is vital for an energy audit, and it speeds the study and improves the accuracy of results. However, inadequate instrumentation should not be an excuse for not conducting an energy audit. Often, experienced plant personnel, would be able to estimate energy flows from aggregate measured data and design data for plant equipment and systems.

Energy Records. Records of energy consumption, distribution and costs are very useful in the conduct of an energy audit. The more complete, thorough and accurate the records are, the more useful they become. Records should be available to evaluate seasonal variations and sustained trends. Here again, a lack of records should not be used as an excuse for deferring a plant energy study. One of the recommendations of good energy audit in such cases is to recommend a set of practical ways of initiating and maintaining a good energy record system.

Conclusion

Energy audit is a vital element in the entire energy management programme, which includes many managerial and operational activities and responsibilities. The energy audit process is essential to the implementation of a successful energy conservation programme in any organization.

An energy audit is not an end in itself. It does not save energy; it merely indicates areas with the greatest potential for energy (and monetary) savings, and therefore, areas where further action needs to be concentrated. It also provides a starting point or a baseline from which progress on energy conservation can be measured.

If an external consultant is appointed for energy audit, an intense interaction between plant personnel and the study team is essential for a proper understanding and a meaningful analysis of the plant's energy options. Without the active participation at all levels, savings in energy use cannot be expected and realized.

Thermal Insulation*

Whatever form it comes in, energy is a precious commodity these days with a value that cannot be measured by money alone. And no one in a factory is more acutely aware of this fact than a factory manager who has been entrusted with the responsibility for energy efficiency.

Some energy losses from systems and equipment in a factory cannot be prevented. But many losses can, and they need to be systematically tracked down and eliminated. A good case in point is the thermal systems/ equipment such as hot/cold ducting.

Although bare lines carrying hot or cold fluids can still be found in factories today+, they are the exception rather than the rule. No conscientious factory manager is likely to allow such conditions to last very long before action is taken in the way of insulation.

But what about the less obvious situations represented by piping/ducting with insulation that has deteriorated or is inadequate by current standards? In either case, whether excessive heat is given out by a hot line or absorbed by a cold one, energy is needlessly wasted.

The problem here lies in defining what an `excessive' energy loss is, and that judgment is almost always drawn on economic lines. In this light, it is important to recognize the economics of energy use has been changing rapidly over the past few years. Pipe insulation that was considered completely adequate under yesterday's relaxed energy outlook may no longer be satisfactory in today's setting of curtailed energy supplies and escalating fuel prices.

Factors such as these point to the need for a careful reassessment of the current state of insulated piping in the factory as well as the practices used in selecting, installing and maintaining duct insulation. The time is ripe for instituting a systematic programme of upgrading the condition of ducting to a level more in keeping with the priorities of an energy shortage economy.

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* Adapted from Industrial Pipe Insulation Materials - Part I and II, Active Conservation Techniques, Monthly Bulletein of Petroleum Conservation Research Association, September and October 1989.

+ The energy study team from TERI found bare lines and inadequate insulation on the ducting for carrying hot air to the withering troughs in one or two factories in November 1989.

A System Perspective

In any effort of this type, consideration should not be limited to just the thermal properties of the insulating material. For example, flanges and fitting in an otherwise well insulated ducting system are sometimes left bare in the belief that heat losses from these parts are too small to justify the expense of insulating them, and too much botheration when insulation has to be removed during maintenance. The fact is that the losses from such parts can be surprisingly large.

For example, an insulated tee in an 8-in steam line, for instance, can lose around 2300 kcal/h when the line is carrying steam at 100 psi(g) pressure. For a system that operates 7200 h/yr, the yearly loss is roughly equivalent to the heating value of 450 gallons of fuel oil. Suitable insulation that would prevent close to 90 per cent of this loss could probably be installed at a cost well under one year's savings. A similar case can be made for other types of fittings and service conditions.

Condition of the insulation is also an important factor. As the velocity of air moving across a heated surface increases, so does the heat loss from that surface. For properly insulated and sealed surfaces, this effect is very small. However, if the insulation has cracks and crevices through which the air may circulate, the heat loss can increase significantly. It is essential, therefore, that all hot-line insulation be tightly sealed, especially when it is used on pipes located outdoors. In the latter case, the insulation needs to be protected from the weather as well as being sealed against the infiltration of air.

Focus on Materials

All of the suggested measures are representative of good application practices that can contribute significantly to the integrity and effectiveness of insulated piping system. But the main thrust of any serious insulation upgrading program must be directed at the insulation materials to make sure they are adequate for the job in terms of economic criteria based on current and predictable energy cost levels. The object is to find the "economic insulation thickness" - the thickness at which the sum of the costs of lost heat and installed insulation is at a minimum.

As a consequence of rising fuel costs over the last 10 years, the economic pipe insulation thickness value has been growing steadily and for many industrial hotline applications, has at least doubled. Impact of this change is dramatically illustrated with a hypothetical example.

In an insullation of 100 ft of 1.5 - in. pipe, with an operating temperature of 120°C, ambient temperature 27°C, and a depreciation period of 20 years, the economic insulation thickness is 2 in. Ten years ago, this economic insulation thickness would have been 1 in. The amount of energy conserved per year by using the thicker insulation is 25.45x10^6 kcal, which results in a saving of Rs. 10,000 if coal is the fuel.

Achieving such savings however, requires an understanding of the types and properties of available thermal pipe insulation materials, and a systematic approach to their selection. Basically, there are three major considerations that govern selection of these materials; operating temperature conditions, heat transmission characteristics, and installed cost. The first two are concerned with specific materials properties while third is an application factor that also has a direct bearing on economic thickness value.

Operating Temperature

All insulation manufacturers categorize their materials by service temperature ranges. And there are a number of different materials on the market currently, offering a variety of choices that cover the full spectrum of industrial requirements from -230° to 1100°C and higher. An array of typical industrial pipe insulation materials is shown in Figure 1.

It is interesting to note that many of the materials with maximum service temperatures of 425°C or less are also recommended for cold-piping applications (under 25°C). The same does not hold true for most of the elevated-temperature materials (650°C and above), which are recommended primarily for hot-line service (35°C and up). The most prominent exception is mineral wool.

Heat Transmission

The rate of heat transfer through an insulating material is dependent on the internal resistance of the material, the resistance at the pipe surface, and the difference in temperature between the pipe surface and the surrounding air. The internal resistance of the material to heat flow, in turn, is directly proportional to its conductivity, k, sometimes called the 'k factor'.

Thermal conductivity, k, is a specific property of a material, defined as the rate of heat transfer in a given direction (perpendicular to the face of the material) per unit thickness per unit time per unit temperature difference per unit area. Its dimensions usually are J.cm/hr.m^2°C.

Conductivity values vary with the mean temperature of insulation. If insulations of different manufacturers are being compared, this temperature effect should be kept in mind.

Thermal conductivity, k, should not be confused with the overall rate of heat transfer coefficient 'U' which is defined as the quantity of heat transper per unit area per unit time per degree difference in temperature. The coefficient U is dependent upon the shape and thickness of the insulating material and the surface resistance of the pipe; conductivity is not.

The lowest conductivity values - greatest resistance to heat flow - are provided by urethane foam materials. Next lowest on the scale are the fibreglass materials, followed, in order of increasing conductivity value, by elastomers, cellular glass, and the elevated temperature materials.

Installed Cost

When insulation materials are being evaluated for their suitability in a given application, the only cost that counts is the final installed cost. Initial price of the materials is generally a poor criterion on which to base value judgments. It is not uncommon to find that a relatively expensive material actually has a lower in-place cost than a less expensive material because of differences in installation requirements.

Properties of Insulation Materials

Pipe insulations are furnished in various forms. Rigid materials such as calcium silicate, cellular glass, fiberglass, urethane foam, etc., come in preformed split cylindrical sections or curved segments 3 to 4 ft in length. Flexible materials such as the mineral wools and foamed elastomers, as well as others, are provided as blankets prefrabricated to fit the pipe size. In addition, there are granular materials, such as Uintate, which is used primarily for the insulation of buried piping.

Both the rigid and flexible insulations are fitted around the pipe/duct; held in position with clamps, wire, or tape; and then locked in place with an outer cover or jacket. A variety of materials are used as pipe coverings, ranging from mastic coatings to coated paper and canvas to vinyl and PVC sheets to thin (.016- in. thick) aluminium, steel and stainless steel jackets. Sometimes the covering is supplied with the insulation and may even be attached to it. In other cases, it may have to be purchased and applied separately.

Although some of these coverings provide an additional insulating effect, their main function is to protect the insulation from damage. The metal jackets are, by far, the most expensive coverings. They are always recommended for outdoor piping, especially where severe weather conditions are encountered. The metal jackets are also used indoors as a measure for improving the fire-resistance rating of insulated piping systems.

All of these factors - the type of insulation material and covering, and the ways in which they are furnished and applied - have a direct bearing on the installed cost. Another important point concerns the availability of preformed elbow and fitting covers. If these are not available from the manufacturer, it would be advisable to find out what expense will be involved in custom fabricating these items.

Pipe insulations are normally furnished in thickness ranging upwards from half in. in increments of 1 and 1/2 in to a maximum of 4 in. Greater installed thicknesses are possible by using two or more material layers, and most insulations are available in nesting sizes designed to provide a snug fit for multiple-layer arrangements. This provision is especially helpful in energy conservation efforts, since piping/ducting insulation can be readily upgraded to current economic thickness levels by adding layers of material rather than tearing out and replacing existing insulation.

The Final Choices

Whether insulation is being selected for a new piping/ducting installation or as a part of an upgrading program for an existing insulated piping system, certain basic information must first be assembled. A good starting point is offered by the specifications checklist outlined below. With this data as a base of reference, selection of a suitable insulating material can usually be made by a process of elimination. A preliminary screening of available insulation materials can be carried out through a study of manufacturers' literature on their materials to narrow the range of choices to a few products. In this analysis, the basic criteria are the operating temperature and the thermal conductivity k. For hot-line applications, any material with a higher maximum service temperature can be used. However, as the graph of thermal conductivities indicates, the value of k tends to be less as the maximum temperature limit of the material decreases.

After this preliminary screening, the selection possibilities that emerge can usually be further narrowed to a single material by a careful evaluation of insulation properties in terms of specific application requirements and a comparison of installation costs for the various materials as estimated by manufacturers or from data supplied by them. Once this choice has been made, the only step remaining is to determine the economic material thickness.

In this computation, the factors that need to be taken into account include present and future fuel costs, capital investment in plant and insulation, the cost of capital, amortization period, maintenance costs and hours of plant operation..

The economic insulation can be found through a systematic calculation process as given below:

1. Calculate the cost of heat loss for a given length of pipe (say 20 m) for a range of insulation thicknesses. This cost is determined by multiplying the total heat loss from the pipe (kcal/hr x number of operating hours per year) by the fuel cost (rupees per kcal of fuel heating value) and dividing by the combustion efficiency, remembering that the fuel cost used here must be a projected value reflecting the average fuel price over the economic life of the insulation.

   The insulation heat loss data needed for these calculations can usually be obtained from manufacturer's literature.

2. Calculate the installed cost of the insulation for the given length of pipe and divide by the amortization period (yr). An allowance for insulation maintenance expenses and interest on the investment should be included in the installed cost value.

3. For each insulation thickness, total the costs calculated in steps 1 and 2. When these total costs are tabulated in the order of increasing insulation thickness, a clear pattern will usually emerge: the total cost progressively decreases, reaches a minimum value and then begins to increase. The insulation thickness corresponding to the minimum total cost is the economic thickness.

When thermal piping insulation specifications are approached systematically as outlined here, the result is maximum energy savings within the bounds of sound economic practices.

Conclusion

The areas at the tea factories where thermal insulation is required are (1) Ducting for carrying hot air from burners to the withering trough, and (2) Ducting for hot air to the driers.

The energy study team from TERI had found that there is a need for insulating, adding insulation and/or upgrading insulation in the above ducting. The cost-benefit analysis, and the economic thickness of insulation can easily be calculated.

A rough estimate for energy savings due to proper insulation of the ducting is in the range of 5-10 per cent of fuel currently being burned in the four factories* visited by the study team.

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* The tea factories visited were at Dekorai, Bargang, Monabarrie and Pertabghur.

Array of typical industrial pipe insulation materials, which are identified in legend below

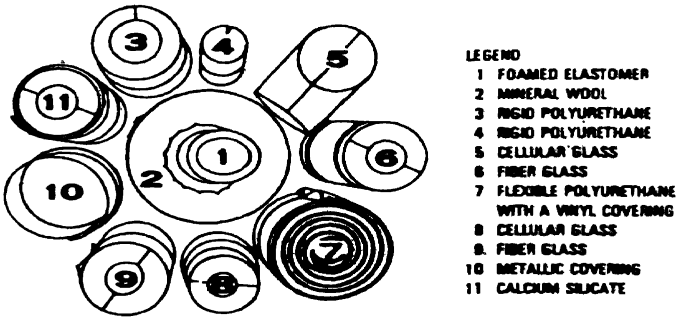
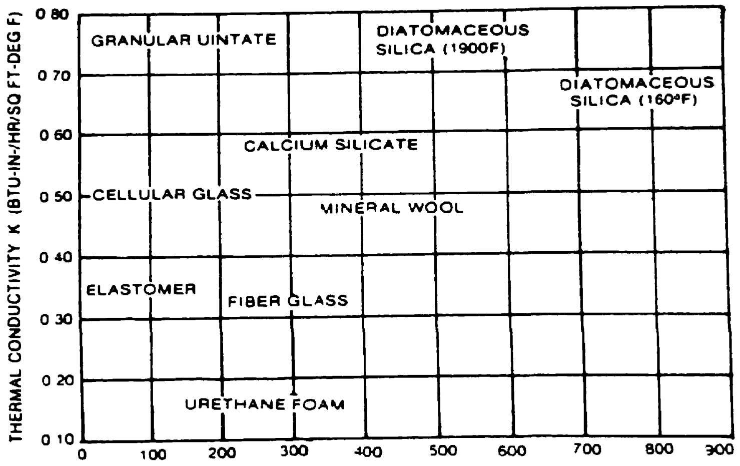


FIGURE 1



Approximate conductivity (k) values for typical industrial pipe insulation materials. Plots for urethane foam, elastomer, and Uintate are based on manufacturer's data. All others were developed by Thermal Insulation Manufacturers Association, Mt Kisco, NY, from ASTM (Specification C-612) and ASHRAE data. For k values and temperature limits of specific insulation materials applications, manufacturers should be consulted.

SERVICE TEMPERATURE RANGES OF COMMONLY USED INDUSTRIAL PIPE INSULATION MATERIALS

MATERIAL	TEMPERATURE	0	200	400	600	1200	1800	2400
CALCIUM ALUMINA-FERRO SILICATE*							1600	
CALCIUM SILICATE*						1200		
CERAMIC FIBERS* (ALUMINA SILICA)								2000
CELLULAR GLASS	-450					800		
FIBER GLASS	-60			450				
FOAMED ELASTOMERS	-40		225					
MINERAL WOOL	-150							1900
UINTAITE		35		460				
URETHANE FOAM (FLEXIBLE)	-50		200					
URETHANE FOAM (RIGID)	-250		225					

*Hot line service only

THERMAL PIPE INSULATION SPECIFICATIONS CHECKLIST

Duct Size
-m

Duct Length
-m
Service
-Hot
-Cold

Pipe Surface Temperature
-Maximum (°C)

Ambient\Air Temperature

-Maximum (°C)
-Minimum (°C)
-Mean (°C)

Duty Cycle
-hr/yr

Location

- Inside
- Outside
- Above Ground

Atmosphere
-Corrosive

(Corrosion Agent)
-Wet

Allowable Heat Loss
(Or Heat Gain)
-kcal or kJ/m

Insulation Material Requirements
- Thermal Conductivity
  (k factor)
- Strength
- Chemical Resistance
- Moisture Resistance
- Weight (per m)

Insulation Material Thickness

- Minimum (cm.)
- Maximum Allowable (cm.)

Covering
- Standard
  (supplied by manufacturer)
- Integral

- Separate
- special

Fire Rating

- Insulation

- Cover

Material Cost

- Insulation
- Cover

- Vapour Barrier

Installation Time
- hr or days

Installation Cost
- Rs./m

Deliver Time
- Days

Training Programme on
Energy Management at
Macneill and Magor Limited, Assam
February 26 & 27, 1990

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Electrical Energy Conservation in Motors
by

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Introduction

Electric motors in industry constitute the single largest component of the electrical load and account for about 72 per cent of the total electrical energy consumed by the industrial sector. Both AC - squirrel cage induction, slipring induction and synchronous -, and DC motors find application in industry. Squirrel cage induction motors are the most widely used because of their low cost, reliability of operation and ruggedness. In a recent study conducted by TERI on industrial electric motors, it has been estimated that squirrel cage motors form almost the entire load below the size of 20 hp and in fact, account for nearly 70 per cent of the entire motor load. Slipring, synchronous and DC motors are normally used in higher ratings and for specific applications. It has also been estimated that in industries without electrolytic loads, motor electricity consumption accounts for 80 per cent of the total consumption.

At the Macneill and Magor tea factories, all the motors are three-phase squirrel cage induction motors and the motor load and the electricity consumed in these account for almost the entire connected electrical load and electrical energy consumption of the factories. For example, at the Pertabghur estate the total connected load is about 1389 kW of which domestic load accounts for about 28 per cent. The remaining load is almost entirely accounted for by motors used in various sections of the factory. Lighting load forms a small percentage of the total load and an even lesser portion of the electricity consumption since lighting is not normally used during daytime.

In view of these facts, the importance of energy conservation in motors cannot be understated.

Motor Selection and Appliction: Electric motors are used to provide motive power to equipment such as compressors, pumps, blowers and a variety of diverse equipment which find application in industry. It is important that the industrial user define his need accurately to enable proper selection of motor for a particular application.

When selecting a motor for any application, the following points should be considered.

1. Process requirements; general, automatic/non-automatic control, variable speed

2. Type of motor and starter

3. Electrical system requirement

4. Availability, reliability and maintenance

It is frequently observed that motors of rating higher than that required for the application are used. There are several reasons for this. Original equipment manufaturers tend to keep a large safety factor in selecting the motor, which results in underloading of the motor. Underloading of the motor may also occur as a result of under utilization of the equipment. For example, an equipment manufacturer would provide for a motor which can take up the load when the equipment is utilized to its full capacity; the user may not utilize this capacity thus leading to underloading.

Before going into some of the aspects of motor performance and means of reducing motor electricity consumption, a brief review of the factors affecting motor performance are given below.

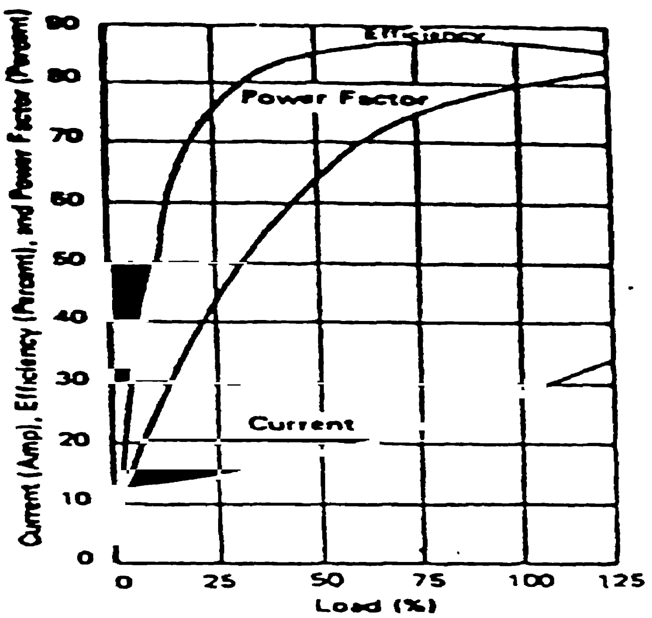
Factors Affecting Motor Performance. The efficiency of an electric motor is the ratio of the mechanical energy delivered at the rotating shaft to the electrical energy input at its terminals. The efficiency with which this transformation takes place is determined by intrinsic losses occurring within the motor; these losses can be reduced only by changes in the motor design.

Figure 1 shows the typical variation of efficiency, power factor and input current with load for an induction motor. Part load performance characteristics depend on motor design and vary from motor to motor. For operating loads in the range of 50-100 per cent of rated load, the efficiency reduction is not very significant but the power factor drops considerably. On further reducing the load, both power factor and efficiency decrease and the effect is drastic at very low loads.

Intrinsic motor losses can be categorized in two groups - no-load or fixed losses, and load or variable losses. No-load losses, as the term implies, occur even when the motor is unloaded and are relatively constant over the entire load range. The fixed losses in a motor comprise of magnetic core losses and friction and windage losses. Load losses vary with the motor load and consist of stator I^2R losses, rotor I^2R losses and stray load losses. Figure 2 shows the variation of the different types of losses with load.

Magnetic core losses or iron losses consist of eddy current and hysterisis losses in the stator and rotor magnetic structure. They are independent of the load and depend on the voltage, core steel material and its physical geometry. Friction and windage losses are caused by friction in the bearings of the motor and the windage loss of the ventilation fan and other rotating parts. These losses are also constant over the entire load range.

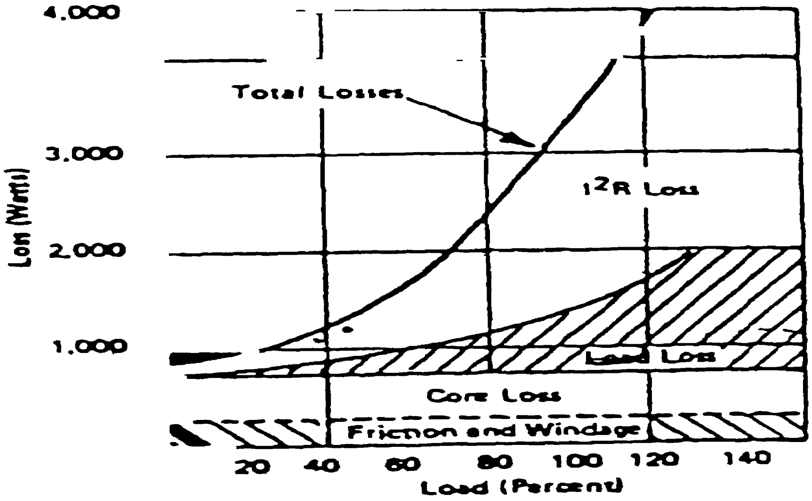
FIGURE 1



TYPICAL PERFORMANCE CURVES FOR DESIGN B.
10-HP, 1800RPM, 220-V, THREE-PHASE, 60-HZ INDUCTION MOTOR

Source: Arthur D Little, Inc., Energy Efficiency and Electric Motors prepared for Federal Energy Administration, Washington, D.C., 1976.

FIGURE 2



TYPICAL LOAD VS. LOSS CURVE FOR DESIGN B.
50-HP, 1800 RPM INDUCTION MOTOR

Source: Arthur D Little, Inc., Energy Efficiency and Electric Motors prepared for Federal Energy Administration, Washington, D.C., 1976.

Copper losses (I^2R losses) are caused by currents flowing through a resistive path and are a function of the square of the current. Stray load losses are residual losses arising from a number of elements and are difficult to either measure directly or calculate. They are proportional to the square of the rotor current. The factors that affect different types of losses in an induction motor are given in Table 1.

Motor performance is also affected considerably by service conditions such as voltage and frequency, and voltage unbalance across the three phases. Voltage unbalance can be more detrimental to motor performance and motor life than voltage variation.

Another factor affecting efficiency is the practice of rewinding of burned-out motors. Through proper rewinding, motor efficiency can sometimes be maintained at previous levels. However, in a majority of instances, poor workmanship and poor rewinding practices result in loss in efficiency.

Energy Conservation in Motors. Electricity consumption in motors can be reduced by operational improvements and retrofit improvements.

Operational Improvements

- operate at rated voltage and balanced supply
- improve controls
- regular maintenance
- improved cooling

Retrofit Improvements

- Replacing oversized motors by motors of lower rating
- Replacing old and inefficient by new motors
- Replacing exising motors by energy efficient motors
- Use of proper controls, variable speed drives

Perhaps the most significant savings in motor electricity could be affected by proper selection of type and rating of motor. Underloading of motors has several disadvantages, such as:

- Lower motor efficiency
- Poor power factor
- Higher first cost of motor and control gear

It has been often observed that in many industries, motors of high ratings are selected to drive high inertia loads where special motors designed for high starting torque, but of lower rating, would have been more suitable.

Table 1 Factors Affecting Losses in an Induction Motor

Iron Loss		Copper Loss		Frictional Loss	Windage Loss	Load Loss
Hysteresis loss	Eddy current loss	Stator loss	Rotor loss			
Material - hot rolled/cold rolled/cold rolled non-grain oriented steel	Conductivity of core steel	Operating load	Operating load	Bearing size and type	Type of enclosure	Operating load
Loss in W/kg of steel at operating flux density	Operating flux density	Conductivity of winding material	Conductivity of winding/bar material	Weight of rotor	Heating produced due to other losses	Overhang of winding
Slot dimensions and wedges	Lamination thickness and uniformity	Cross-sectional area of winding	Cross-sectional area of winding/bar	Type of lubricant	Type of fan - unidirectional/bi-directional	Tooth harmonics
Stator-rotor slot combination (slot harmonics)	Core packing factor	Winding arrangement	Rotor length	Temperature of lubricant	Speed of rotor	Air gap flux density
Core packing factor	Inter-lamination insulation	Length of winding	Skin effect in winding	Alignment of shaft	Physical shape and dimensions of fan	Burring of laminations
Power frequency	Stator-rotor slot Combination (slot harmonics)	Skin effect in winding	Temperature of winding	Position of shaft - horizontal/vertical		Ratio of air gap to rotor slot opening
Slip at operating load	Slip at operating load	Temperature of winding		Speed of rotor		Bonding of rotor bars to rotor laminations
Age of steel	Power frequency	Slip of rotor				
	Age of steel					

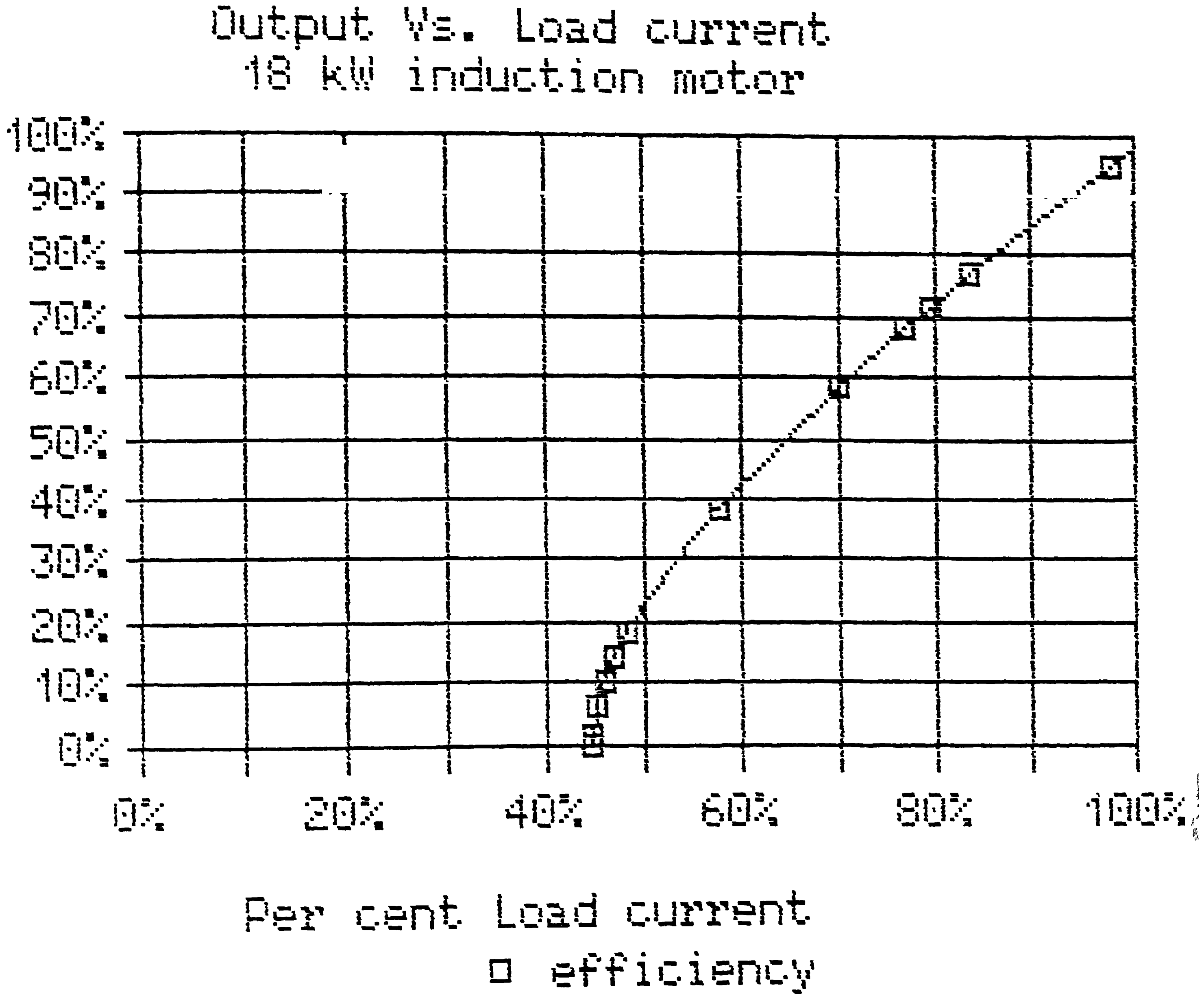
For applications which have varying load patterns, it is not advisable to select a motor based only on the highest load to be taken by it. Instead, an optimum rating of motor may be selected based on the loading cycle and the time for which the motor has to operate at each load during the cycle. The optimum rating in such cases is the equivalent steady-state rating which would result in a temperature rise equal to that of the defined load cycle. The optimum rating may be calculated using the relation:

$$hp = \sqrt{\sum_{i=1}^{n} \frac{(hp_i^2 \times t_i)}{T_e}}$$

where, t_i is the cycle time for which the motor operates at a load of hp_i, and T_e is the effective cooling time for the entire load cycle; which is equal to t_i for running periods of the motor, and equal to one-fourth of t_i for the time the motor is not operating during the cycle (Since there is not effective cooling during the motor off-time). However, this method of motor selection, for varying load applications, is not suitable for applications requiring frequent starting or reversing or for high inertia loads. It might be possible in many instances to select a motor of a slightly lower rating and operate at overload for a very short period of time (without exceeding the thermal capacity of the motor insulation), instead of selecting a motor of high rating to operate at full load for a short duration. This method of calculating the motor rating, however, is not suitable for motors subjected to frequent starts/stops and for motors operating high inertia loads.

Under operating conditions, however, it is normally quite difficult to ascertain the load on the motor to decide whether or not motor is underload. The load on the motor can be determined only by measuring input parameters such as power, current, voltage, speed and frequency, under both; load and no-load conditions. It is not advisable to determine the load on the motor based on the motor load current alone since this could lead to misleading results. Figure 3 shows the variation in motor current for varying load for a typical 18 kW (25-hp) motor. It can be seen from the figure, that at a load current of 60 per cent, the output is only about 42 per cent of the rated value. Therefore, it is important to have adequate instrumentation to be able to conduct tests on motors to determine the operating load, operating efficiency and operating power factor.

FIGURE 3



Output Vs. Load current
18 kW induction motor

Based on the results of such tests it could be determined if the motor could be replaced by a new motor (of the same rating) which would operate at a higher efficiency, or by a motor of lower rating which would operate at an improved load factor, and consequently at improved efficiency and power factor. An improvement in the efficiency by even a few percentage points could result in significant savings depending upon the operating hours and the tariff structure. Lower input results not only in lower energy charges but also in lower demand charges due to reduced kVA demand.

For example, consider the replacement of a 11 kW (15-hp) motor operating at 100 per cent load and at an efficiency of 85 per cent and at a power factor of 0.8, by a new motor (also of 11 kW):

Existing Motor

Motor Rating	11 kW
Operating Efficiency	85 %
Operating Power Factor	0.8

Replace by New 11 kW Motor

Operating Efficiency	89 %
Operating Power Factor	0.85

Annual Savings in Electricity	4650[*]	kWh	
Annual Savings in Demand	20	kVA	
Annual Savings in Energy Charges	4650[+]	Rs.	
Annual Savings in Demand Charges	1200[+]	Rs.	
Total Annual Savings	5850	Rs.	
Cost of New Motor (Apprx.)	11000	Rs.	
Salvage Value of Old Motor	2750	Rs.	(@25 %)
Net Investment	8250	Rs.	
Simple Payback Period	1.4	years	

Similarly by replacing an oversized motor by a motor of lower rating, considerable savings in motor electricity consumption could be effected.

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[*] Based on annual operation for 8000 hours

[+] Based on a tariff of Re.1/kWh and at a demand charge of Rs. 60/kVA.

Energy Efficient Motors: Energy efficient motors are motors having higher efficiencies, which can be obtained by incorporating design improvements to reduce intrinsic motor losses. Motor losses can be reduced by taking several measures such as, using low-loss steel, increasing the active material by incorporating a longer core length, using thinner laminations, reducing the air-gap between stator and rotor, using copper bars in the rotor instead of aluminium, by using superior bearings and a smaller fan, etc. As a result of these modifications, costs of energy efficient motors are also higher than those for standard motors.

Energy efficient motors are now available in the country which have efficiencies higher by 3-4 per cent over those for standard motors. The power factor is also higher and a further advantage is a fairly flat performance characteristic over a wide range of load (typically 50-100 per cent). These motors cost about 30 per cent more than equivalent standard motors. Even so, the savings which could be achieved at such improved efficiencies justifes the additional expenditure incurred on the motor. The economics, however, depend on the operating hours and the electricity tariff. Usually, motors operating for less than 2000 hours/annum are not good candidates for replacement by energy efficient motors.

The selection of energy-efficient motors should be based on several factors in addition to those considered for selection of a standard motor:

1. Electric power-saving and life-cycle-cost comparison to standard motors

2. Improved ability to perform under adverse conditions such as abnormal voltage (Generally, the energy-efficient motors have superior performance characteristics under abnormal voltage conditions.)

3. Lower operating temperature

4. Noise level

5. Ability to accelerate higher-inertia loads than standard motors

6. Higher operating efficiencies at all load points (At all loads, the energy-efficient motor presents the opportunity for energy savings,)

Energy-efficient motors are however, not suitable for the following types of loads:

- Multispeed
- Frequent starts and stops
- Very high-inertia loads
- Low-speed motors (below 720 rpm)

In the tea factories, energy efficient motors could be used for all applications such as fans, blowers and CTC/ rolling table machines.

Power factor correction: Induction motors inherently operate at lagging power factor due to the magnetizing current drawn by the motor (which is essential for the creation of the magnetic field to transfer power from the stator to the rotor). The use of capacitors to improve the power factor has several advantages such as,

- reduced kVA demand, thereby reducing demand charges
- reduced I^2R losses in cables, thereby reducing energy charges
- reduced voltage drop, leading to improved voltage regulation
- a resultant increase in overall system efficiency

The rating of capacitor required for a particular motor depends upon the no-load kVAR requirement of the motor, which can be determined only by conducting no-load tests on the motor. It is recommended that the capacitor kVAR should not exceed about 90 per cent of the no-load kVAR of the motor. Alternatively, a safe value of capacitor may be installed depending upon the motor rating. Table 2 gives the recommended value of capacitor to be used for standard motors with different number of poles.

Since a reduction in line current, and the resultant improvements, are reflected backwards from the point of application to the generator, the maximum benefit from power factor correction can be achieved if the capacitor is connected across the motor terminals.

It should be ensured that capacitors of higher ratings than those required are not installed since this could result in over-voltages which could cause the motor to burn-out. Adequate protection should also be provided for the capacitor to discharge when it is switched off.

However, the installation of capacitors at individual motor terminals would be subject to the economics of installing low rating capacitors, and the savings that could be achieved by their installation. At the Macneill and Magor tea estates, however, the economic benefit may not be significant since ASEB has a one-part tariff based only on the energy consumption and demand charges are not levied. Therefore, monetary savings would be achieved mainly through reduction of line losses in cables and improved voltage regulation.

TABLE 2

Power Capacitor Ratings (Nominal) for Direct Connection to Induction Motors

	Capacitor kVAR at Motor Speed of:					
Motor hp	3000 rpm	1500 rpm	1000 rpm	750 rpm	600 rpm	500 rpm
5	2	2	2	3	3	3
7.5	2	2	3	3	4	4
10	3	3	4	5	5	6
15	3	4	5	7	7	7
20	5	6	7	8	9	10
25	6	7	8	9	9	12
30	7	8	9	10	10	15
40	9	10	12	15	16	20
50	10	12	15	18	20	22
60	12	14	15	20	22	25
75	15	16	20	22	25	30
100	20	22	25	26	32	35
125	25	26	30	32	35	40
150	30	32	35	40	45	50
200	40	45	45	50	55	60
250	45	50	50	60	65	70

Note: The values in the above table are based on average conditions and efficiency to maintain a p.f. of 0.95 to 0.97 between 33.3 to 125 per cent of rated load and is applicable to motors of 220, 400/440, & 3300 volts, 50 Hz.

Other options for reducing motor electricity consumption

Use of multispeed motors. Multispeed motors are of two types (i) single winding, and (ii) double winding. The former has a stator winding which can be connected to give two different speeds having a ratio of 2:1. The two winding motor has two separate stator windings, so that two different synchronous speeds can be obtained. With a change in connection therefore, four different speeds can be obtained with a two winding motor. Multispeed variable torque motors have a horsepower rating proportional to the square of the speed, i.e., the horsepower rating decreases with the square of the speed. Such a motor would be suitable for applications such as blowers for withering troughs where the air-flow requirement changes over a period of time with the wither.

Use of delta-star changeover switch. Delta-star changeover switches make use of the fact that at lower loads, the motor has better performance characteristics in star connection as compared to that in delta connection. As the load reduces below about 50 per cent of rated load, the stator winding is reconnected in star. This leads to better performance at low loads. It might be possible to use such changeover switches for rolling table machine motors where the load reduces over a period of time. However, its use could be decided upon only after ascertaining the characteristics of the load on the motor over a period of time.

Use of flat belts for transmission drives. Transmission drives such as pulleys and belts, and gears transmit mechanical rotational power from the prime mover shaft to the shaft connected to the mechanical load such as a machine, blower or a fan. The simplest form of transmission drive is the belt drive which is least expensive, light and quiet in operation. The belt drive transmits power solely by the frictional grip between the belt(s) and the pulley. The belts consist of tension strands which serve to absorb the tractional forces operating in the belts, which are covered with an elastomer. The elastomer holds the strands together and provides surface friction for power transmission.

In many conventional belt drive systems, V-belts are normally used. New materials have made possible the manufacture of flat belts with better performance characteristics. Unlike the V-belt that develops additional lateral frictional forces, the flat belt develops only the tangential forces. This reduces the stress on the (flat) belt and results in lower heat generation due to lower lateral compression and elongation. Moreover, the flat belt is free from the effect of heating at the edges that results in hardening of rubber and reduction in the frictional grip.

Due to the higher transmission efficiency of flat belts, savings in the range of 5-12 per cent can be achieved in the motor input power (10-12 per cent savings have been achieved in industries where flat-belts have been used) The payback period is normally less than one year.

Maintenance

A large number of equipment and processes in industries are dependent on the electric motor for their operation. It is, therefore, essential that motors be properly operated and maintained to ensure reliable and efficient operation. Motor losses increase significantly without proper maintenance. For example, improper lubrication can cause increased friction in both the motor and associated drive transmission equipment; the electrical resistance of conductors increases with temperature which results in increased copper losses in the motor. By providing adequate ventilation and by keeping motor cooling ducts clean, heat can be effectively dissipated thereby reducing losses and also increase the life of insulation (for every 10°C increase in motor operating temperature over the recommended hot spot temperature limit, life of the winding is reduced by half).

The list below shows some of the important items that should be checked regularly to ensure proper motor operation:

- Inspect motors regularly (at least annually) to detect wear in bearings, housings, and for dirt and dust in motor ventilating ducts

- Check load condition to ensure that the motor is not over or underloaded. A change in motor load from the last test indicates a change in the driven load, the cause of which should be identified and corrective action taken as needed. Load tests can be conducted at the time of normal motor inspection or on a continuous basis if permanent instrumentation is installed.

- Take extra care in lubrication. Motors should be lubricated in accordance with the manufacturer's recommendations, but care should be exercised not to over-lubricate. Excess oil or grease from the motor bearings can enter the motor and saturate the motor insulation, causing premature failure and a possible fire.

- Watch alignment. Check periodically for proper alignment of the motor and the driven equipment. Improper alignment can cause shafts and bearings to wear quickly, resulting in damage to both the motor and the driven equipment.

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G. Sambasivan
TERI, New Delhi

urvey-Based Lubrication Program nproves Machinery Performance

:. GREENE, W. R. FORD AND E.M. KIPP

'he potential for cost reductions achievable through a well-designed and implemented machinery rication program is often not apparent and usually ısiderably greater than realized by corporate nagement. Too often, the appropriate selection and imum use of lubricants are assumed to be a rather ple, insignificant procedure by company officials.

common result of this low corporate esteem is that ıy plants do not make the effort to reliably document performance of lubricants. Consequently, impor- t factors such as specific numbers and lengths of cheduled machine downtimes; cost of replacing d or damaged parts, including lower production ability; and causes of failure (about 50% of all ıponent failures are premature and lubricant ted) are ignored.

ven more regrettably, operating problems directly ted to inadequate lubrication are unrecognized eventually become accepted as normal operating edures. On the other hand, a well designed and lemented, scientifically based lubrication program ls to awareness of inadequate machine element igns and other maintenance deficiencies not ctly related to the lubricant involved, and creates a itive impact on corporate profits.

ajor developments are rapidly occuring in the mistry and physics of lubricants. New methods for ieving major improvements in antiwear and load- ring capabilities of materials used for the ıufacture of gears, bearings and other machinery ıents are becoming more available. A plant ication engineering program unaware of the ntial interactions between improved tribological erties of machine elements and the selection and er use of lubricants does not attain maximum lts.

any plants still use too many lubricants, often 'operly, than necessary for optimum performance. ıdardization, reduction in number, and improved ication are urgent objectives of an advanced plant ication program. Technologies developed by cant suppliers and additive manufacturers in the ormance capabilities of their products make it ible to lubricate 95% of a large and diverse plant less than six general types.

In addition to identifying the minimum number and types of lubricants required for optimum costs, an effective plant program should address three problems: quality assurance testing, maintenance of lubricants in the as-new condition in instances where they are circulated and reused, and practices required for compliance with EPA and other constrainsts.

Solutions to these problems may require effective filtration systems or related maintenance techniques, lubricant sampling and analysis programs, and implementation of procedures to discover probable reasons for failure in various machine elements. It is also important that a lubrication engineering program, supported by appropriate corporate staff resources, provide periodic training workshops.

Plant Lubrication Survey

Planning and implementing the initial survey are major factors in determining the quality of the final lubrication schedules and the success of the plant program. A minimum lubrication survey should investigate several factors:

- Identify equipment and component parts requiring lubrication: the specific location of each machine: and the model, serial number, function, manufacturer, operating instructions, and limitations.
- Obtain similar information for each subcomponent of the machine, such as drive motors, gears, couplings and bearings.
- Examine the lubricant recommendations made by the machine or parts manufacturer, and supporting documentation for these selections.
- Determine the lubricants currently used.
- List the schedules in effect for each lubrication point, including frequency, quantity applied and sampling schedules; provide similar information for all machine components.
- Identify the nature of each lubrication point, and whether circulating systems are fed from central storage tanks or individual machine sumps, or grease fittings; and whether manual, semi-automatic, or automatic equipment is used. Operating characteristics of the lubrication systems encountered should be determined.

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ive Conservation Techniques
thly Bulletin of Petroleum Conservation Research Association,
Delhi, October 1988

Make a detailed visual inspection of each machine ıd its components for indications of problems such ı leakage, excessive noise, high temperature, ɔration, and loose, damaged, or missing parts.

Record information relating to the adequacy of the ɜchine to perform its intended functions.

An effective approach for conducting the initial ɔricant survey is to start at one end of the plant and ɔve to the other, floor by floor, starting from the sement. When surveying an individual machine, ırt at the power source and follow through each wer train identifying the couplings, reducers, and ɜrings.

tablishing Lubrication Schedules

Current lubrication schedules discovered in the ɪal plant survey should be reviewed, including type, ount, and intervals for each point. Then determine ɘther it is the best lubricant for the job, and if its ılity is commensurate with the overall objectives of ucing the total number of products needed for erior performance.

he next step is to conduct a detailed review of each ɔhine to consider whether the equipment is quate for the intended function, the machine igner has provided for optimized lubrication, and ropriate access to the elements is available. New ipment lubrication specification should be under- ıd prior to the equipment's installation.

perating records such as frequency of scheduled unscheduled downtimes and the reasons for each down are important documents in preparing the lubrication schedule. Maintenance methods used for all lubricants other than "once through" types should be gathered. Lubrication records should be prepared to document type of filtration, total quantities consumed per unit of time, and scheduled samplings for laboratory tests designed to detect excessive wear, contamination, and additive depletion.

The new standard plant survey should also provide for periodic checking of the quality of lubricant shipments, and for changes in storing, handling, dispensing, and applying practices. Good housekeeping procedures in the storage area are an excellent investment because machine operational problems are often caused by use of the wrong lubricant, contamination between stored products, and using improperly cleaned transfer equipment.

Survey information serves as the basis for selecting the minimum number and types of lubricants required in the plant. The new survey reflects the feasibility of reducing the number of products used by employing improved multifunctional lubricants, and designing an appropriate schedule for each machine and its elements.

Major advances in the formulation and manufacture of lubricants make it possible to substantially reduce the number of lubricants needed to provide high quality service of all machinery and component elements. For example, Reynolds Metals Co. uses just five groups of standard machinery lubricants to handle 95% of its needs; specialty products handle the other 5%. A fully implemented lubrication programe often reduces the plant's annual repair and maintenance costs 5 to 20%.

(Courtesy: Plant Engineering, June 23, 1988, pp 52-53)

How to Cut Domestic Electrical Energy Cost

A lot of energy is used in our homes. Very often we use more than we really need to, sometimes unwittingly. Some of the energy is wasted. Here are some tips for saving electricity in homes.

1. Awareness

Each member of the household should be aware of the need to conserve electricity and avoid waste. If any light/fan/a.c./appliance/equipment is not required, it should immediately be turned off. Excessive use of artificial lighting should also be avoided. As far as possible,daylighting and natural ventilation and air circulation should be used. These simple measures, which are normally neglected, would save considerable quantity of electricity.

2. Lighting

As far as possible, fluorescent (FL) lamps should be used in various rooms in the house. The fittings used must be of good quality (known name brands are preferred).

If low voltage is a problem, FL lamps should be supplemented by incandescent lamps of sufficient wattage. Outdoor lighting should preferably be from FL lamps.

3. Appliances

(i) The refrigerator is the biggest energy consumer in your kitchen. It is also the biggest energy consumer in your whole home if you do not have an air-conditioner.

Unlike other appliances, the refrigerator operates automatically 24 hours a day, every day, to keep your food at the right temperature. So it is important to make sure your refrigerator is working efficiently.

Right Capacity. Select the right capacity refrigerator for the size of your family. You should also consider your marketing habits, how often you go to the market and the amount of food you store. As a guide, allow at least 60 litres for the first 2 members of your household and 30 litres for each additional person.

Defrosting. Regular defrosting is necessary to keep the refrigerator at optimum efficiency. Do not allow more than 6 mm of ice to build up in your freezer. Before buying a new refrigerator, compare the energy rating of various models and choose the most economical one. Frost-free refrigerators usually consume more energy but do not require defrosting.

Thermostat Setting. Adjust the thermostat to the setting recommended by the manufacturer. Do not set the temperature lower than needed. Over-cooling wastes energy.

Door Fit. Check the refrigerator door gaskets and hinges for leaks. The gasket is the strip of flexible plastic or rubber which seals the crack between the door and the compartment when the door is shut. To test for leaks in the gasket, place new rupee note between the door and the cabinet. Close the door and pull at the rupee note. You should feel a slight resistance. Test all round the door. If there are places where the rupee slides out easily, adjust the hinges, replace the gasket or do both. A faulty gasket wastes energy.

Keep the door closed. Think of what you need before opening the refrigerator door. When you open the door, close it quickly to keep the cold air in and the warm air out. Each time you open the door, warm air gets into the refrigerator and this must be cooled. It requires energy to cool it.

Adjust Legs. Make sure the front legs of the refrigerator are higher than the rear ones so that the door closes automatically when released.

Ventilation. Position your refrigerator in a well-ventilated place with enough space from the walls to allow for free circulation of air around the condenser coils. A space of at least 150 mm between the condenser coils and the wall should be allowed. Insufficient ventilation will cause the condenser coils to overheat and overload the compressor.

Keep condenser coils clean. Keep the condenser coils at the back of your refrigerator clean and free from dust, lint and grease. These act as insulators and prevent heat from escaping to the surrounding air. If the coils are dirty, more energy is required to maintain the same temperature inside the refrigerator. Clean the condenser coils at least once a year with a cloth or a soft brush.

Food Arrangement. Arrange foods in the refrigerator compartment with space between items so that air can circulate freely. For greatest efficiency, keep your refrigerator well-stocked. For the freezer compartment, stack items tightly. Fill empty spaces with bags of ice, if necessary.

Cool down hot food. Allow hot foods or liquids to cool before storing them in the refrigerator.

Covering Contents. Liquids should always be covered when stored in the refrigerator compartment, otherwise they add to the humidity and the compressor has to work longer. Covering foods and liquids is also more hygenic and helps seal in the flavour.

During Vacation. If you are away from home for a few days, switch off the refrigerator. Clean the interior and leave all doors slightly open. The larger your refrigerator, the greater your energy saving will be.

Many of these ideas will cost you nothing. Some will cost you only a few rupees. But they all will cut down on the energy you use and save your money, without your having to sacrifice any of the comforts you are used to.

(ii) Air conditioners

Air conditioners are highly energy intensive. Therefore, proper selection of air conditioners with higher energy-efficiency in mind is a must. Each room should have enough capacity of air-conditioning, so that air conditioners operate on an on/off mode.

Filters must be cleaned regularly (once a month recommended) and the condenser and evaporator coils cleaned once a year. Thermostat must be set at the highest comfort temperature (between 25-28^{o}C in the room) to save electricity. It would be advisable to turn the air conditioner on only when the room is used, and turn it off soon after the last person leaves the room. There is practically little benefit in turning air conditioners on much before a room is used.

(iii) Toasters, ovens, blenders, water heaters and irons

It is advisable to use only ISI-marked appliances when available. All plugs and plug points should be of high quality (ISI marked) so that loose contacts and burn outs can be avoided. Loose contacts lead to heat generation and dissipation, which results in higher energy consumption.

(iv) Fans

Proper selection of size of fan for each room is important to ensure sufficient air circulation. There is very little difference in energy consumption for various sizes of fan.

Electronic regulators should be used to save electricity at low and intermediate speed operation. With such regulators up to 20 per cent saving in electricity is possible. Morevoer, speed regulation is much smoother than with the conventional regulators.

Corporate and Enterprise-Level Energy Management

by

V.S. Kothari*

WHY ENERGY MANAGEMENT ?

Energy is a vital input to industrial production. The high levels of energy use in Indian Industry compared to other countries, the increasing problems of energy unavailability, and the rising costs of energy point to the use of energy management at the enterprise level as a sound strategy to reduce costs, improve productivity, and increase profitability. In most cases, energy management can lead to 15-20 per cent savings in the short- and medium-term with low requirements of capital investments. These savings can generally be achieved irrespective of the size of the organization and the manufacturing activity it is engaged in.

This paper describes the approach and considerations that go into developing a programme for rational use of energy at the enterprise level. Broadly, this comprises four phases:

- Establishing a management structure for energy management
- Initiating energy management activities
- Managing the programme once it is under way
- Maintaining energy management activities permanently

ORGANIZING ENERGY MANAGEMENT

The most essential requirement for a successful energy management programme is the commitment and dedication of the top management. They must be totally convinced of the need and benefits of energy management. They must be willing to provide the resources, both personnel and capital. They must visibly demonstrate and communicate their commitment to the employees of the enterprise.

Once a corporate decision has been made to start an energy management programme, a special management structure within the company's organizational framework needs to be created in view of the special role of energy as a common input across different divisions, departments and sections.

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* Formerly with TERI. Currently at Isotem Services Private Limited, New Delhi. Original paper has been modified to suit Macneill and Magor's requirements.

The first step in this process is the appointment of a corporate energy manager in Macneill & Magor Limited. The person appointed to this post should be a senior manager and should report directly to top management. This also serves to demonstrate to all employees the importance attached to energy management. This position requires full-time attention. The person appointed as corporate energy manager must be knowledgeable about all aspects of the company's operations and energy usage, committed to energy management, influential and assertive.

Though the appointment of a corporate energy manager is preferred, as an alternate to appointing a corporate energy manager, the Company could entrust the coordination of energy management programmes to a strong engineering department at their corporate office. The two touring engineers could be included in the coordination activities.

In all tea estates, the Factory Managers should be made the principal coordinators of energy conservation programmes. At the tea factories, Assistant Managers should be made the focal point of energy management activities. The Factory Manager at an estate would be primarily responsible for providing leadership in the energy conservation efforts at an estate.

A useful practice is for the energy managers/coordinators to be assisted by a committee consisting of advisors, touring engineers, head tea house babus (supervisors) and operators. This committee would assist in developing programmes and formulating plans, serve as a channel for communication back to personnel in their functional area, and also serve as a forum for review and generation of ideas. Membership in this committee could be rotated on a planned basis to involve a greater number of people and get more ideas.

INITIATING ENERGY MANAGEMENT

With the appointment of a corporate energy manager or an engineering department responsible for energy management and the establishment of an appropriate energy management, structure, the process of planning and initiating energy management activities can be undertaken. This comprises three major steps :

- Setting overall energy management policies

- Conducting estate/factory energy studies
  (energy audits)

- Formulating a plan of action

Step 1 : Setting Overall Energy Management Policies

The first step is setting of overall policies relating to objectives, goals, methods, resources, etc. Some of the questions that should be addressed in this context are:

- **What are the objectives of the energy management programme ?** These could be minimization of energy wastage through better housekeeping, improvement of efficiency of energy consuming equipment, substitution of expensive or scarce fuels, incorporation of better operating and maintenance practices, training of operators for energy-efficient operation, etc.

- **What are the goals ?** These can be expressed in terms of expected reduction in energy consumption or energy costs over a specified time period.

- **What are the possible methods to achieve the desired objectives and goals ?** These could include plant energy studies, incorporation of technological developments, equipment modification or replacement, streamlining of operating procedures, etc.

- **What resources - personnel and capital - are to be commited ?**

- **How will the achievement of objectives and goals be monitored ?**

Clearly, these questions cannot be answered without some knowledge and understanding of the plant's energy consumption patterns and trends. This requires at least an analysis of historical data on the quantity and costs of various forms of energy used within the plant, and the specific consumptions or energy intensities, i.e., the ratio of energy inputs to production outputs. These analyses are very useful in highlighting major trends in energy consumption at the overall corporate or factory level.

It would appear that some of these questions would be better addressed as the energy management programme progresses. This is indeed so. Nevertheless, it is very important, and in fact essential at the very outset to define overall policies, even in somewhat preliminary fashion, which would serve as the basis for an initial commitment. As the programme proceeds, these policies should be reviewed and revised, if necessary.

Step 2 : Conducting Factory Energy Studies

To save energy, it is necessary to know where, how and how much energy is being consumed. The objective of factory energy studies, also referred to as energy audits, is to characterize and quantify the use of energy within the factory at various levels – in sections, major processes, and major equipment. The factory energy study provides a comprehensive and detailed picture not only of the type and quantity of energy being used but also how efficiently it is being utilized, the mechanisms by which energy is being lost, and the amounts of energy thus being lost.

Factory energy studies can be carried out in two sequential phases – a preliminary study and a detailed study.

The preliminary factory energy study or preliminary energy audit is essentially, as the name implies, a preliminary data collection and analysis effort. Readily available data on the factory's energy systems and energy-using processes or equipment is obtained and studied. The operation and condition of equipment are observed by going around the factory and discussing aspects of these with plant personnel. The data and observations are then blended with personal experience to develop recommendations for immediate short-term measures, and to provide quick and rough estimates of savings that are possible and achievable. A preliminary study usually identifies and assesses obvious areas for energy savings such as inefficient and insufficient lighting, poor or missing insulation, condensate recovery, idling equipment, deterioration and deficiencies in combustion and heat transfer equipment (e.g., dryer), water wastes, etc., and serves as a basis for the detailed factory energy study.

The detailed factory energy study is a comprehensive analysis and evaluation of all aspects of energy generation, distribution and utilization within the plant. The analysis is based on consistent and detailed accounting of all energy inputs into a system and all energy outputs from a system which results in the development of energy and mass balances. At the plant level, the analysis requires time-series data on a daily, monthly, or yearly basis on the quantities of all forms of primary energy flowing into the plant, e.g., L.D.O., H.S.D.O., T.D. oil and electricity, and production figures of made-tea. At the section level, information is required on the quantity of energy forms and utilities consumed, and the production figures of intermediate products. At the equipment level, in addition to the quantities of energy forms and material products, process parameters such as temperature, pressure, flow, etc. are also required.

Data generation and collection are essential and critical elements of a detailed factory energy study. Difficulties in meeting data requirements generally arise due to unavailability of plant operating data, inadequate instrumentation, poor accessibility of equipment, unavailability of factory design data, and unavailability of historical records. The acquisition of actual operating data through existing or new permanently installed instruments or portable test instruments cannot be overemphasized in this context.

Measurements are critical in any serious effort to conserve energy. Apart from helping to quantify energy consumption, measurements also provide a means to monitor equipment performance and check equipment condition. Examples of measurements and instrument types are :

- Flow/Velocity: Orifice plate, pitot tube, venturi tube, turbine meter and anemometer

- Temperature:Thermometers - bimetallic, resistance, etc., thermocouple, radiation pyrometer

- Pressure: Bourdon gauge, diaphragm gauge, manometers

- Heat Flow : Thermography equipment

- Electrical: Multimeter, ammeter, wattmeter, power factor meter, light meter

Analysis and evaluation of data lead to identification of various measures that would save energy. These measures are then evaluated with regard to their technical and economic feasibility resulting in recommendations for further action.

An energy audit is not an end in itself. It does not save energy; it merely indicates areas with the greatest potential for energy (and monetary) savings, and therefore, areas where further action needs to be concentrated. It also provides a starting point or baseline from which progress on energy conservation can be measured.

The duration of these studies depends on factory size and complexity. The preliminary energy study can be carried out in two days. The detailed study would require anywhere from three months to six months of effort. Factory energy studies can be carried out in-house if adequate resources and expertise are available. Alternatively, or additionally, external assistance may be sought from energy consultants, equipment vendors, and engineering and design firms. In either case, intense interaction between plant personnel and the study team is essential for a proper understanding and a meaningful analysis of the factory's energy options. Too often, the factory energy study is considered to be the consultant's 'problem', resulting in minimal inputs and involvement from factory personnel. This attitude is counter-productive and self-defeating. Without the active participation of all levels, savings in energy use cannot be expected and accomplished.

Step 3 : Formulating a Plan of Action

In most cases, drawing implementation plans can begin even while the factory energy study is under way. This is particularly so for measures emphasizing better housekeeping which are usually low capital but manpower intensive options. Once the energy audit is complete, it should be carefully reviewed and a detailed implementation plan devised. At this stage, the overall energy management policies formulated earlier should also be reviewed and suitably amended, if necessary. For example, the energy audit may indicate that the goals set earlier were too low, and an upward revision may be required. Goals should be tough but realistic.

The implementation plan must include specific time schedules for specific projects or categories of projects. Individual responsibilities must also be assigned. Management must exercise due control and authority to ensure that plan implementation is as per schedule. Periodic progress reviews at quarterly or half-yearly intervals should be carried out to assess implementation progress, to ensure that anticipated savings are being realized, to review any energy savings opportunities identified subsequently, and to assess the impact of changes in factors such as energy prices, production levels, production mix, etc. on the energy conservation programme.

MANAGING ENERGY MANAGEMENT

Having initiated an energy management programme, proper management is essential to reap the benefits that are expected. Two major elements of this managerial function are motivating employees to participate and contribute, and monitoring of progress.

Motivating People

Employees can be motivated to support and actively participate in an energy management programme through:

- Awareness and Information
- Involvement
- Incentives and Rewards
- Publicity and Promotion

Awareness and Information

In most factories, employees have little or no idea of the amounts of energy being consumed within their factories, their section and even the equipment being operated by them. In such a situation, energy conservation obviously carries no meaning. Employees can be stimulated to support energy management by making them aware of the amounts of energy they are using, the associated costs, the many ways to save energy, the dependence of energy consumption on other factors such as production rate, and the importance of energy conservation for the company's profitability and the nation's growth. The information can be provided in the form of comparisons of historical trends, current values and goals for overall energy use, energy intensity, etc. in both physical and monetary terms; energy conservation checklists for each manufacturing operation outlining simple and routine housekeeping measures to save energy, audio-visual presentations, and other general literature.

Information must be presented in a manner which facilitates comprehension. If the information is too technical, too much, too sketchy or too dull, it is likely to be ignored or not understood. Terms that employees can relate to in everyday life should be used. For example, a sign saying 'Stop Oil Leaks' will not be as effective as a sign saying 'One drop of oil every five seconds costs Rs. 1,000 per year'.

Training is also an important means of both informing and involving people at all levels in an energy management programme. For operating personnel, training is required in energy-efficient operation of equipment and the practicalities of energy saving. This could be integrated into the company's other training programmes. Upper level management also need to be informed of the overall energy situation, energy costs in relation to other costs, the energy management programme - its goals, achievements, technical, economic and behavioural aspects, etc.

Involvement

Motivation is based on involvement. Commitment and a sense of personal accountability can be generated only through total involvement of factory/estate personnel at all stages from initiation to implementation of the energy management programme.

Involvement must begin with the top management. As mentioned earlier, top management must be fully committed to the energy management programme and must visibly demonstrate their commitment and involvement in every manner possible and at every available opportunity. Top management must originate the programme, generate momentum and then maintain momentum. Adequate personnel and financial resources must be provided and responsibilities delegated to implement activities and projects to achieve the predetermined energy conservation goals. Progress should be monitored and goals reviewed and revised in the best interests of the Company.

Operators and maintenance staff should be involved actively as they are ultimately responsible for execution of activities in the programme. Also, they are often in a better position to recommend areas for savings or improvements. The most effective way of involving them is by simply going out and talking to them regarding goals, achievements, problems, and progress or lack of progress. This demonstrates to them that the energy conservation programme is real and also that their role is important in success or failure of the programme. Another means of involvement is through training.

Head tea house babus (supervisors) should be involved by assigning them responsibilities for implementing and monitoring activities, and by getting them to interact and communicate with operations and maintenance staff on progress and problems. If possible, energy management activities should be made a part of each supervisor's performance or job standards.

Incentives and Rewards

Another method of motivating people is through incentives and rewards. Monetary rewards could be given to employees for suggestions leading to substantial energy savings, for innovative ideas or solutions, and for outstanding efforts in implementation of energy conservation activities. Wide publicity of effective ideas provides an added incentive in the form of public recognition. Other incentives could be designed to meet the needs and attitudes of factory/estate personnel.

One possible danger with monetary rewards is that it makes people accustomed to receiving extra compensation for an effort that really is part of their job. If rewards are stopped later, there could be a reduction in ideas that could affect original gains.

Publicity and Promotion

Publicity and promotion are essential to make the energy management programme successful. These aid in monitoring employees through the three methods mentioned above. Some suggestions for publicizing and promoting an energy management programme are listed below[1/]:

1. One article per month is written in the Company newsletter, if one exists. Include a personal profile on people performing energy management activities and at least one good energy conservation idea that was implemented.

2. Posters and pamphlets on energy conservation.

3. Note paper pads with different energy conservation opportunities and ideas printed on the paper.

4. Energy conservation performance results for factory and sections are posted monthly by the factory manager.

5. Assistant Manager conducts quarterly on-site reviews, a walk-through of the unit looking for energy-saving opportunities.

6. An agenda item on energy conservation is included at staff meetings.

7. Energy conservation material is provided to supervisors for hourly employee discussion periods at least quarterly.

8. Quarterly meetings are held in the factory for all unit representatives.

9. Annual meetings are held by factory manager.

10. An Energy Awareness Day is set aside in the factory twice a year.

15. A Company energy logo is developed and adopted.

[1/] Adapted from Williams, M.A., Initiating, Organising and Managing Energy Management Programs, in Turner, W.C. (ed.), Energy Management Handbook, John Wiley, New York, 1982.

Monitoring and Reporting

Monitoring of the energy conservation programme is necessary to ensure that it is on schedule and that established goals and objectives are being met. Programme momentum can also be maintained through monitoring. This requires tracking of selected measures of performance.

Selection of the appropriate and relevant measures is essential for proper monitoring. For example, at the factory level, energy usage or cost trends could be tracked. However, these are not unique measures by themselves. Energy usage could also vary due to changes in production volume or production mix. Energy costs would also change due to increases in prices. A better factor is the energy intensity, or energy consumption per unit output, although even this is a function of production rate. Another method could be the use of an energy conservation index wherein current energy use is adjusted to compare with energy use in a certain base period.

Starting from the overall Company or factory, monitoring should be carried out at the lowest level possible. This allows closer monitoring of progress and deviations, and faster response to overcome problem areas.

Effective monitoring requires that a reporting system be developed and instituted. Report contents and frequency should be tailored to the audience. Reports to top management could be submitted quarterly giving monetary savings, energy savings, capital expenditures and other expenses, and measures of performance such as energy intensity or energy conservation index, all shown against their goals, and a brief description of activities for each factory or group of factories/estates. Reports to factory managers would be more detailed and more frequent, say monthly. Reports should contain more specific and detailed information at lower levels. For a few key areas, such as peak electrical demand, reporting could be on a hourly, daily, or weekly basis to monitor energy consumption or wastage more closely.

Installation of required instrumentation, acquisition of necessary data, proper maintenance of factory log sheets, and consistent energy accounting are essential for reporting and monitoring. In this context, it is important to reiterate the need for instruments and measurements not only during the energy audit phase but also during subsequent implementation of energy-saving schemes.

MAINTAINING ENERGY MANAGEMENT

Energy management is not a one shot affair. Rather, it should be a continuing programme whose focus and strategies may change over time. The overall objectives, however, are invariant.

Results of the energy management programme should be reviewed annually to determine whether the objectives and expected savings have been achieved. Based on the review, policies should be reassessed and the plan of action revised. The energy reporting system should become an integral part of existing management information systems. Employee motivation should be sustained. Technological developments should be continuously monitored and evaluated. A frequently neglected aspect is the contribution of a good preventive maintenance programme to effective energy management. Only by sustaining the momemtum and the efforts will energy savings continue to accrue.

CONCLUSION

More than ever before, energy management is the need of the hour. It is easy and simple, involving the application of well-known principles and techniques. It is also cost effective. Irrespective of the size of a tea factory/estate, an energy management programme can be initiated in a few months, and savings can be realized almost from the beginning. An energy management programme in Macneill and Magor would be a sound investment with returns comparable to the best elsewhere.

INDUSTRIAL ENERGY*

CONSUMPTION, CONSERVATION AND POLICIES

by

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1. Introduction

The industrial sector (manufacturing industry) in India has traditionally been the largest consumer of commercial energy in the Indian economy. In 1987-88, about 35 per cent of the total commercial energy available was consumed in the industrial sector. In terms of the total final consumption of commercial energy, it was approximately 51.4 per cent. The contribution to this sector from non-commercial energy sources, such as bagasse, rice husk and solar energy is negligible.

The industrial sector, being the more organized sector, is the prime candidate for implementation of energy conservation measures. As in many other developing countries, in India the potential for energy conservation remains high and it is virtually untapped.

In contrast with developing countries, the industrialized countries responded to the two oil crises of the seventies more purposefully and more rigorously. The outstanding examples of energy conservation measures adopted were generally confined to the industrialized countries. For example, between 1973 and 1982, in the EEC countries the GDP grew by 9 per cent whereas the energy consumption fell by 9.5 per cent. Japan has also achieved a steady economic growth at 5 per cent per annum with energy consumption decreasing every year. Many of these countries were able to decouple the economic growth from the growth in energy demand.

This paper discusses the commercial energy use pattern in India's (manufacturing) industrial sector, energy conservation potential, obstacles to energy conservation and government policies and policy recommendations.

2. Energy Use Pattern in India's Manufacturing Industry

In 1986-87, about 520 trillion kilocalories of commercial energy was consumed by industry as purchased fuels and electricity. Coal, oil and gas accounted for about 88 per cent of the total energy used in industry; the rest of the commercial energy was from electricity.

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* In this paper, the power sector is excluded.

Table 1 presents the breakup of energy consumption in the industrial sector for 1986-87. Since 1980-81, the overall industrial consumption has grown at an annual rate of 6 per cent.

In the case of coal, the industrial sector consumed about 46.6 per cent of the total coal consumed in India. For oil the corresponding figure is 15.8 per cent, for gas 25.4 per cent and for electricity approximately 52.5 per cent. This data is given in Table 2. The oil, gas and electricity consumption in industry has been growing more rapidly than that of coal. While the share of oil and gas in the total national energy consumption is increasing, that of electricity in industry has been decreasing steadily, though at a slow rate.

The demand for energy is highly sensitive to the kind of industrialization strategies that the country pursues. If a high value-added manufacturing strategy based on low energy consumption industries is pursued, a consequent decline in the elasticities (ratio of rate of growth in energy consumption to GDP growth rate) for fuel and electricity would be possible.

In the recent document indicating the perspectives for 2004-05, the Advisory Board on Energy has estimated electricity demand for the industrial sector at 280 billion kWh and 367 billion kWh for 1999-2000 and 2004-05 respectively. If these estimates are to hold, the demand for electricity in 1994-95 can be interpolated at around 185 billion kWh, showing an increase of almost 50 per cent during the 8th Five-Year Plan period.

Coal use in the industrial sector is mainly in the form of coking coal for steel industry, and non-coking coal for cement, paper and paperboard, newsprint, and brick industries. A large cluster of small industries generally accounts for around 20 per cent of the total coal consumption.

If there was to be no improvement in the efficiency of coking coal use in industry, the demand in the years 1989-90, 1994-95, 1999-2000 and 2004-05 would be 41, 60, 75 and 88 million tonnes (Mt) respectively.

In the case of non-coking coal, efficient processes and changes in raw materials in cement, nitrogenous fertilizers, pulp and paper industries are expected to bring about reduction in coal use.

Table 1

Break-up of Commercial Energy Consumption in Industrial Sector

(1987/88)

Energy Form	Quantity	Mtoe	Energy, 10^{12} kcal	% of total
Coal	80.22 Mt[1]	39.308	400.9	74.0
Oil	7.269 Mt[2]	7.063	72.0	13.3
Natural Gas	268 M cu.m	0.23	2.3	0.4
Electricity	78,010 MkWh	6.501	66.4	12.3
Total		53.102	541.6	100.0

Mtoe - million tonnes of oil equivalent

1/ Includes coking coal including the quantity imported, and coal used as feedstock

2/ Excludes oil used as feedstock, but includes LPG used as fuel

Source: Tata Energy Data Directory and Yearbook (TEDDY) - 1989, Tata Energy Research Institute, New Delhi.

Table 2

Commercial Energy Consumption in Industrial Sector vis-a-vis National Commercial Energy Consumption

(1987/88)

Energy Form	Nation (Mtoe)	Industry (Mtoe)	% of Total
Coal	88.196	39.308	44.6
Oil	43.724	7.063	16.2
Gas	3.216	0.23	7.2
Electricity	13.322	6.501	48.8

Source: TERI Energy Data Directory and Yearbook (TEDDY) - 1989.

As regards petroleum products, the industrial sector uses oil products generally at a rate of 0.004 kg per rupee of value added. If this norm was to continue unchanged, the demand in the year 2004-05 would be about 17 Mt of petroleum products.

On the basis of the above projections, the predicted demand for electricity, coal and petroleum products are as shown in Table 3 below.

Table 3

Future Demand Projections for Electricity, Coal and Petroleum Products in Industrial Sector by Advisory Board on Energy

	Estimated Requirements		
Year	Coal (Mt)	Petroleum Products as Energy Source (Mt)	Electricity (Billion kWh)
1989-90	89.2	6.11	120
1990-95	120.0	8.53	185
1995-2000	150.0	11.81	280
2004-05	188.0	16.62	367

The growth rates represented by the above figures indicate that the demand for energy in the industrial sector for coal, petroleum and electricity may not be met. Moreover, the constraints in the supply industry are compounded by the transportation and other infrastructure deficiencies. Hence, energy conservation assumes an importance overriding other elements of a long-term energy policy.

3. Energy Conservation Potential

The Inter-ministerial Working Group (IMWG) on Utilization and Conservation of Energy had estimated that in 1983 the total potential for energy conservation in the industrial sector was approximately 25 per cent of the total energy consumption. Table 4 presents a summary of the energy savings in monetary terms reported by IMWG.

Table 4

Manufacturing Industry - Conservation Potential, 1983

Energy Form	Annual Consumption (million tonnes)	Savings Potential (million tonnes)	Investment Required for Creating Equivalent Resource (Rs. crores/ unit)	Total Investment Required (Rs. crores)
Coal	70	17.5	50	875
Oil (As Fuel)	4	1.0	180	180
Electricity	60 billion kWh	5250 MW	0.9	4725
Total investment for creating equivalent energy capacity				5780
Investment required for implementing energy conservation measures				3600
Annual expenditure saving in industrial sector by implementing conservation measures				1925

Source: IMWG's Summary Report on Utilization and Conservation of Energy, September 1983.

It is clear from the Table 4 that the investment required to create additional energy supply is much higher than that required for energy conservation measures. The annual energy savings is at an overall return of over 50 per cent. It is important to note that most of the short-term measures require very little investment, and have payback periods ranging from a few days to 2 years. Long-term measures generally require large investments, and payback periods range from 2-5 years.

In early 1989, Government of India set up a working group on energy conservation for the Eighth Five-Year Plan to identify key areas for formulation of policies and programmes for energy conservation during the ensuing plan period. The working group concluded that at least 50 per cent of the energy conservation potential in the industrial sector should be realized in the Eighth Plan, and the rest in the Ninth Plan. To take up comprehensive programmes, it was estimated that about Rs. 2,700 crores (at 1983 prices) would be needed by the industrial sector. Out of this amount, a large part of the cost would be met by the end-users themselves.

4. Difficulties in Implementing Energy Conservation Measures

In India, the industrial sector is relatively organized and yet highly disparate and dispersed, consisting of a large number of small manufacturing firms. Moreover, the units are of various vintage, using outdated technologies, and in many cases running beyond the design-life of the plant.

Indian industries have some of the highest energy intensities vis-a-vis developed and some developing countries. Though there is a large scope for improvement, there are some important reasons for energy intensities remaining high. These are discussed below.

First, most industries have little incentive to improve their energy consumption rate, as the energy cost forms only a small percentage of the total product cost.

Secondly, in the energy-intensive industries such as steel, aluminium, cement and petroleum refining, there are very few companies, which are essentially oligopolies. Therefore, increased energy costs are easily passed on to the consumers. Even if there are administered prices for their products, lack of profit-motive generally discourages energy conservation. In these large (public sector) undertakings there is little incentive to cut production costs under these conditions.

Thirdly, major conservation efforts require replacement of capital stock, process modifications, retrofits and technology changes, which normally require large investments. Due to paucity of funds, high interest rates, and high demand for industrial goods, the industries generally prefer investing in capacity expansion rather than in energy conservation equipment. Often this means installation of cheap machines, and outdated technology and production systems, which lead to energy inefficiency.

Finally, shortage of raw materials, capacity underutilization, interruption in fuel and electricity supply, lack of commitment to energy conservation, labour unrest, lack of trained manpower, lack of instrumentation and monitoring and absence of good housekeeping practices contribute to high energy intensities.

5. Government Policies in India

The policy instruments adopted so far by the Government of India to promote efficient use of energy in the industrial sector can be divided into two categories, viz., (1) fiscal or economic measures, and (2) liberalization of import of certain energy-efficient equipment.

5.1 Fiscal Measures

In February 1982, Government announced a 100 per cent depreciation allowance, effective April 1983, on certain energy-saving devices and systems. These can be categorized in the following areas:

(a) Specialized boilers and furnaces

(b) Instrumentation and monitoring systems for monitoring energy flows

(c) Waste heat recovery equipment and cogeneration systems

(d) Power factor-correcting devices.

Depreciation at 30 per cent has also been allowed for renewable energy devices, which include:

(i) Solar energy devices

(ii) Wind mills and related equipment

(iii) Biogas plants and engines

(iv) Battery-powered or fuel cell-powered vehicles

(v) Agricultural and municipal waste conversion devices

(vi) Equipment for using ocean waves and thermal energy

(vii) Machinery and plants for the manufacture of any of the above items.

Schemes from Financial Institutions. Both the Industrial Development Bank of India (IDBI) and the Industrial Credit & Investment Corporation of India Limited (ICICI) have introduced two schemes, viz., (a) Energy Audit Subsidy (EAS) Scheme, and (b) Equipment Finance for Energy Conservation (EFEC) Scheme. The schemes will be initially in operation for a period of two years up to the end of the Seventh Five-Year Plan.

Under the EAS scheme, subsidies of up to Rs. 10,000 and Rs. 1,00,000 on preliminary and detailed energy audits would be available. The assistance under the EFEC scheme would be in the form of term loan, up to a maximum of Rs.4 crores per company/undertaking at a maximum interest rate of 14 per cent. The interest rate will be reduced by up to 4 per cent depending on the actual percentage reduction in specific energy consumption values.

Schemes from Petroleum Conservation Research Association (PCRA)

a. Energy Audit Subsidy Scheme

PCRA offers subsidies up to 50 per cent of the cost towards the conduct of energy audit at industrial premises limited to a maximum of Rs. 25,000/- per industrial unit. The above subsidy would be payable after acceptance of energy audit reports both by PCRA and the party after a written commitment from the latter, to implement the recommendations that would result in realising around 50 per cent of the energy saving potential identified in the report.

b. Boiler Modernization Scheme

The rules and guidelines for utilizing PCRA's scheme on boiler modernization are provided in Appendix 2.

5.2 Energy Equipment

Under the import-export policy of the Government, permission in the form of an import license is usually required for import of capital goods and equipment, spares, raw materials, finished goods, etc. However, import of certain goods is allowed free of import license. These are items classified under OGL category. Since April 1983, import of the following energy conservation equipment, including systems and devices working on/used for renewable and alternate sources of energy, has been allowed under OGL.

(i) Wind-driven generators

(ii) Solar energy equipment

(iii) Parabolic focussing systems of the automatic electronic tracking type, including photoelectric sensors

(iv) Portable exhaust gas and combustion analyzers

(v) Steam trap leak detector

(vi) Ultrasonic steam leak detector

(vii) Solar heat control film

(viii) Burners (a few types)

(ix) Infrared thermography instruments

(x) Furnace oil flow meters and steam flow meters

(xi) Low-maintenance steam traps, U.F.O.

Specified equipment in categories (i) and (ii) above are fully exempt from customs duty. Import of the other items is subject to payment of customs duties and levies at prevailing rates.

Complete details of the above incentives, which are applicable to industry, are given in Appendix I.

Other Measures

Apart from the above mentioned policies, the Government has proceeded along two other avenues.

Two governmental organizations - the National Productivity Council (NPC) and PCRA - offer a range of energy conservation services and assistance.

In addition, from time to time, the Government of India has constituted expert groups to examine specific aspects of energy supply and demand, and recommend appropriate policy measures. The four groups appointed in recent times include (1) the Working Group on Energy Policy appointed by the Planning Commission, (2) the Committee on Power, (3) the Inter-Ministerial Working Group on Utilization and Conservation of Energy and (4) Advisory Board on Energy (ABE).

ABE's activities have included formulation of a set of recommendations in various areas of energy conservation, which include power and the industrial sector.

The recommendations of these groups have been published, and some of these are discussed below.

6. Policy Recommendations for India

In the work of the earlier government-appointed committees in India, there was greater emphasis, understandably, on aspects of energy supply. More recently-constituted expert groups have focussed considerable attention on energy consumption and conservation aspects with growing recognition of their importance, and of conservation as an alternate source of energy.

Some of the important recommendations of the expert groups and other experts in this field are given below. (Reference to expert groups are shown against the respective recommendations, and the names of these groups are given in footnotes.)

a. Technical and Operational Measures

- Detailed energy audits should be carried out in at least all large and medium-sized industries.[1]

- Measures to improve the efficiency of energy utilization in industries should be the most important element of energy policies in the industrial sector. Standards for fuel efficiency for each type of industry should be fixed with gradual improvement in efficiency over time, and their achievement monitored.[2]

- Special attention should be paid to savings in the use of oil. Substitution of oil with other types of fuel including coal should be actively pursued[2]

- Cogeneration possibilities in existing industries should be identified and pursued, if necessary by providing financial incentives.[2]

b. Fiscal and Economic Measures

- Investments and subsidies for energy conservation schemes should be created, to be expanded to around Rs. 100 crores every year, over a span of 10 years, by levying an energy conservation cess on industrial consumption of petroleum products, coal and electricity.[3]

- Customs duty relief on both components and equipment should be offered.[3]

c. Energy Pricing

- Energy pricing policies must ensure that (i) sufficient surplus is generated to finance energy-sector investments, (ii) economies in energy use are induced, and (iii) desirable inter-fuel substitution is encouraged.[2]

- Energy prices should be raised so that they at least reflect long-run marginal costs and allow for a reasonable return. A further increase in the form of a conservation cess may be desirable to promote conservation of resources and economy in general use.[2]

1/ Advisory Board on Energy
2/ Working Group on Energy Policy
3/ Inter-Ministerial Working Group

- The energy pricing system should be structured so that the price to the user reflects the real costs of supplying energy.[2/]
- Penal levies on industries, which exceed laid down norms of consumption, and fiscal incentives for those who improve on them should be considered.[4/]

d. Industrial Licensing, Production and Growth

- Before new units are licensed, the capacities of the existing units and the capacity utilization factors for these units should be taken into consideration.
- In setting up new industries, the technologies used should be the least energy-intensive options, particularly with respect to the use of depletable sources of energy and electricity.[2/]
- The possibility of utilizing waste heat from power plants, especially the large super thermal stations, by setting up appropriate industries in the vicinity should be seriously considered.[2/]

e. Organizational Measures

- In large and medium-sized industries, it must be made mandatory to appoint energy managers, who are suitably trained. In small-scale industries, a mechanism of energy auditing, reporting and improvement in energy use should be instituted.

f. Energy Equipment

- Better standards for various energy using equipment must be set.
- Restrictions must be placed on the production and sale of low-efficiency motors and transformers.[4/]
- Manufacture of sophisticated instruments required for monitoring energy flows must be encouraged. Import of such instruments and spare parts should be free of customs duty.

2/ Working Group on Energy Policy
4/ Committee on Power

g. Research and Development

- Each major industrial process should be reviewed to identify the R&D efforts required to reduce energy consumption.[2/]
- R&D programmes in energy conservation technologies should be sponsored by the government as a distinct component of the Science and Technology plan.[3/]

h. Other Measures

- Formal training courses for developing energy conservation expertise should be introduced in various technical institutions to maintain a steady flow of experts in the field.
- A system of governmental recognition and awards should be instituted for honouring individuals and organizations for outstanding performance in energy conservation[3/]
- To create energy conservation awareness, pamphlets in regional languages, suitable documentary films and programmes on radio and television should be introduced.[3/]

7. Conclusion

The industrial energy efficiencies in India are much lower than those of the developed countries and even many of the developing countries. There is vast scope for improvement. Fortunately the need for energy conservation in industry is recognized and the awareness is increasing. However, the action taken by both government and industry is far from being adequate.

It is evident that changes in energy use efficiency in any country will occur voluntarily where the economic choices are clear. But the adjustments that need to be made will vary according to the existing structures and resources endowments of individual economies.

In India, more stringent policies and measures are required to improve energy intensities, and overall energy consumption. It is high time that government acted, before it is too late to control the escalating energy use and wastage. A carrot-and-stick policy may be in order.

2/ Working Group on Energy Policy
3/ Inter-Ministerial Working Group

The tasks outlined by various expert groups in India are comprehensive, though complex and formidable in nature. They require a strong institutional infrastructure and integrated approach for implementation of energy conservation across the board. The experience of other countries points in the same direction and shows that the ideals of conservation can be translated into reality only if they are backed by appropriate administrative, legal and financial inputs. In this regard, it is important for the government to assess as to how best the existing government departments and institutions can be used/restructured to face the challenge.

References

1. TERI Energy Data Directory and Yearbook - 1988, Tata Energy Research Institute, New Delhi.
2. Virendra S. Kothari, Industrial Energy Policies of India, Discussion Paper No.01.85, Tata Energy Research Institute
3. Energy Conservation, Challenges and Opportunities, Advisory Board on Energy, Government of India (1986)
4. Towards a Perspective on Energy Demand and Supply in India in 2004/05, ABE, May 1985
5. Energy Audit Directory, Petroleum Conservation Research Association, New Delhi

APPENDIX I

ENERGY CONSERVATION INCENTIVES*

Incentives currently available to encourage energy saving are listed in this Appendix.

FISCAL INCENTIVES GIVEN BY CENTRAL GOVERNMENT

A. INCOME TAX

1. One hundred per cent depreciation allowance on written-down value is allowed on energy saving devices and systems listed below:

   (Item IIIF(2A) under Part I of Appendix I to the Income Tax Rules 1962, effective from April 1983)

   (a) Specialized boilers and furnaces

   i. Ignifluid/fluidized bed boiler

   ii. Flameless furnaces

   iii. Fluidized bed type heat treatment furnaces

   iv. High efficiency boilers (thermal efficiency higher than 75 per cent in case of coal-fired boilers and 80 per cent in case of oil/gas-fired boilers).

   (b) Instrumentation and monitoring systems for monitoring energy flows

   i. Automatic electrical load monitoring system
   ii. Digital heat loss meters
   iii. Microprocessor-based control systems

   (c) Waste heat recovery equipment and cogeneration systems

   i. Economizers and feedwater heaters
   ii. Recuperators and air preheaters
   iii. Backpressure turbines for cogeneration
   iv. Heat pumps
   v. Vapour absorption refrigeration systems
   vi. Organic rankine-cycle power systems
   vii. Low inlet-pressure small steam turbines

   (d) Power factor correcting devices

   i. Shunt capacitors and synchronous condenser systems.

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* Source: Energy Conservation, Challenges and Opportunities, Advisory Board on Energy, Government of India (1986)

B. CUSTOMS DUTY

Import duty in respect of the following 15 specified energy conservation equipment has been reduced to 40 per cent (35 % + 5 % auxiliary) ad valorem vide Notification No. 30/88 Customs, dated March 1, 1988.)

Sl. No.	Description
1.	Flameless furnaces for reheating and heat treatment applications
2.	High velocity recirculating furnaces for reheating and heat treatment applications
3.	Low excess air burners (below 10 % excess air)
4.	Fuel oil emulsion burners
5.	Regenerative burners for applications in forging and heat treatment furnaces
6.	Self-recuperative burners (Burners using preheated air)
7.	Flat flame burners
8.	Heat pipes for extracting heat from low temperature fluids and gases
9.	Heat pumps for space heating, water heating, cooling applications
10.	Free-ball bucket steam traps with no links/ hinges.
11.	Automatic microprocessor-based load demand controllers for efficient load management
12.	Microprocessor-based combustion control system for boilers
13.	Light sensitive time switches for street light controls
14.	Microprocessor based automatic anode over-potential controllers in caustic, chlorine and aluminium industries
15.	Microprocessor based-universal programmable timers timers for continuous and batch processes, such as in tyre industry and rayon industry.

C. OPEN GENERAL LICENSE CATEGORY

Since April 1983, import of the following energy saving/ conservation equipment, including systems and devices has been allowed by all persons under open general license (OGL) category.

- i. Portable exhaust gas and combustion analyzers
- ii. Steam trap leak detector
- iii. Ultrasonic steam leak detector

In the new Import-Export Policy of 1988-1991 (announced on March 30, 1988), the following items have been brought under OGL:

Capital Goods

i. Machinery and equipment for manufacture of energy-saving lamps having efficiency of lamps more than 60 lumens/watt

ii. Machinery and equipment (excluding furnaces) for the manufacture of fluorescent lamps, sodium vapour discharge lamps and mercury vapour lamps

Energy Conservation Equipment

1. Burners

   a. Zero and low excess air burners
   b. Emulsion burners
   c. Self-recuperative burners
   d. High velocity burners
   e. Flat flame burners
   f. Axial flow burners

2. Instrumentation

   a. Infrared thermography instruments

   b. Furnace oil flow meters and steam meters (volume-shedding and turbine-type)

3. Other Equipment/Items

   a. Low maintenance steam traps, U.F.O.

APPENDIX II

PCRA BOILER MODERNIZATION SCHEME

POLICY GUIDELINES

1. Oil fired, inefficient (thermal efficiency below 70 per cent), IBR Boilers of less than or equal to 50 T/HR capacity are covered in the scheme to be replaced by modern efficient oil/coal fired boilers (thermal efficiency in case of new oil fired boilers $\geq$ 80 per cent and for new coal fired boiler $\geq$ 75 per cent).

2. Boiler should be in operation with the consumer for a period of at least two years.

3. The loan interest rate is 11 per cent - service charge of 1/2 to 1 per cent by oil companies.

4. Loan repayment in easy instalments in 3-5 years.

5. Loans for replacement, capacity 100 per cent in excess than present case may be considered on individual merit.

6. Replacement of stand-by boilers may be considered on individual merit subject to ROI savings levels (Return on investment fuel savings).

7. Loans are given for replacement of oil-fired boilers by efficient coal/leco/lignite fired boilers with following guidelines:

   a. New boiler has thermal efficiency $\geq$ 75 per cent.

   b. Beneficiary furnishes a bank guarantee for 100 per cent of the loan amount; to be renewed annually based on reduced principal amount.

8. Loans for replacement of boilers as well as for feed water treatment plants (WTP) may be given with following guidelines:

   - WTP is an integral part of the boiler.
   - Loan is extended on single point basis. The boiler manufacturer gives WTP and new boiler both.
   - The cost of WTP is $\leq$ 25 per cent of the cost of new boiler.

Analysis of Energy - Related Data From Tea Estates

by
S. Anand

Energy related data was collected from the tea estates at Monabarie, Bargang, Dekorai and Pertabghur during the visit to Assam. Subsequently, additional data was collected from all the 52 tea estates.

An analysis was carried out to determine the energy use pattern for different tea estates. Some of the important results from this analysis are dealt with in this paper.

Based on data collected on the connected electrical load for three tea factories, the break-up of load by different processes was analyzed. It was observed that withering, processing and drying each account for about 22-30 per cent of the total connected load. Sorting and packing account for about 9-14 per cent of the connected load. In this analysis the domestic load was excluded. The results of this analysis are graphically represented in Figure 1.

It was observed that there is considerable variation in the specific energy consumption of both TD oil and electricity for different tea estates. The analysis was carried out separately for factories producing only CTC and orthodox varieties of tea and those producing both the varieties. Tables 1,2 and 3 give the results from this analysis separately for factories producing only orthodox and CTC tea, and for factories producing both the varieties, respectively.

Table 1

Variation of Specific Energy Consumption of TD Oil and Electricity (Orthodox Tea Factories)

	TD Oil (Rs./kg)	Electricity (Rs./kg)
Average	1.64	1.37
Maximum	3.20	2.71
Minimum	0.41	0.48
Standard Deviation	92.07 %	75.75 %
Variance	84.77 %	57.37 %

FIGURE 1

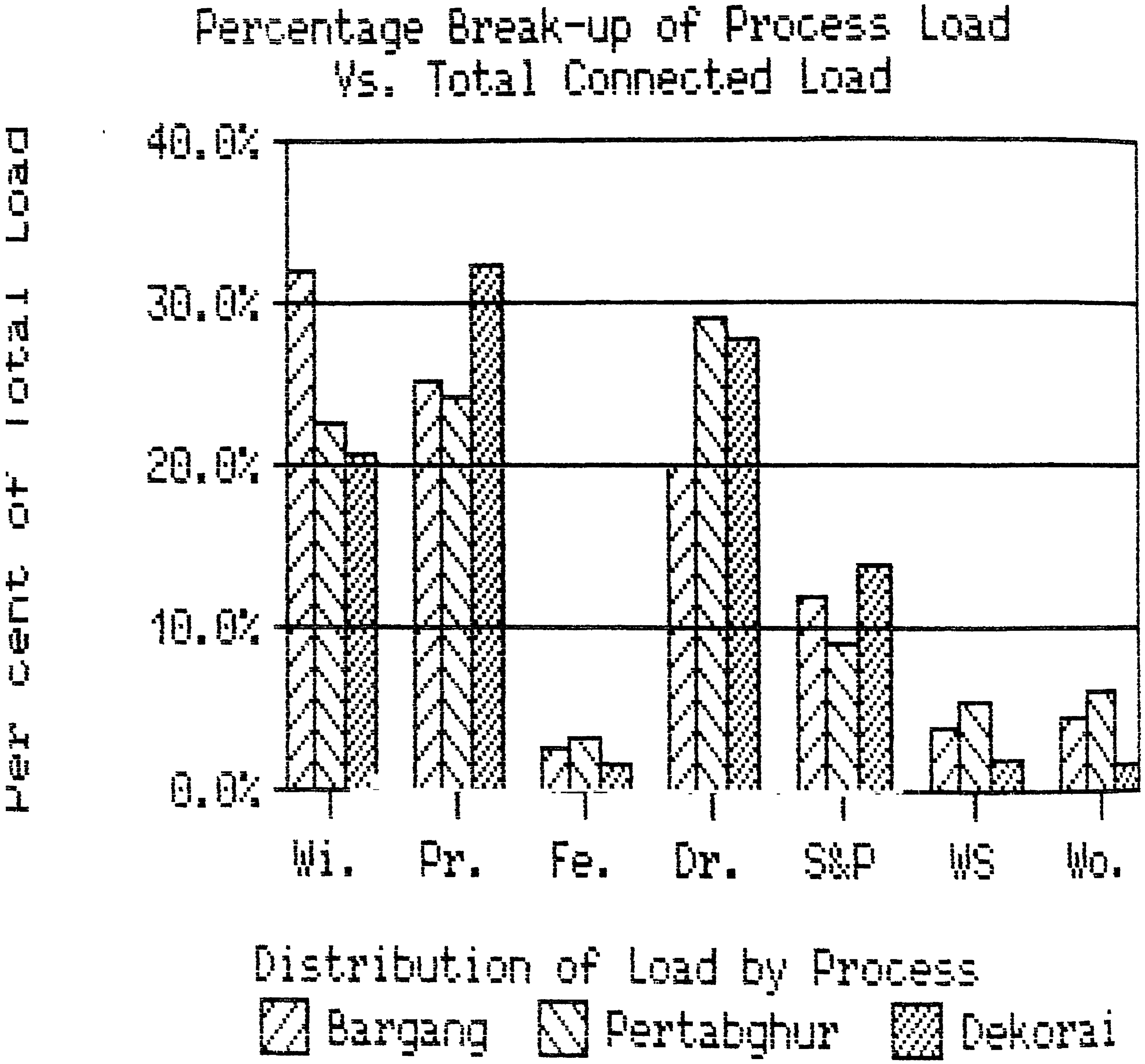
Percentage Break-up of Process Load
Vs. Total Connected Load
Per cent of Total Load
40.0%
30.0%
20.0%
10.0%
0.0%
Wi.
Pr.
Fe.
Dr.
S&P
WS
Wo.
Distribution of Load by Process
Bargang
Pertabghur
Dekorai

Table 2

Variation of Specific Energy Consumption of TD Oil and Electricity (CTC Tea Factories)

	TD Oil (Rs./kg)	Electricity (Rs./kg)
Average	0.53	0.93
Maximum	1.27	1.33
Minimum	0.05	0.63
Standard Deviation	50.54 %	26.18 %
Variance	25.54 %	6.85 %

Table 3

Variation of Specific Energy Consumption of TD Oil and Electricity (Factories Producing both CTC and Orthodox Tea)

	TD Oil (Rs./kg)	Electricity (Rs./kg)
Average	0.82	0.85
Maximum	1.85	1.73
Minimum	0.05	0.31
Standard Deviation	50.51 %	25.91 %
Variance	25.52 %	6.71 %

From these tables we can see that there is considerable variation in the minimum and maximum specific energy consumption of both TD oil and electricity for different tea factories. The variations are much more in case of factories producing only orthodox tea as compared to those which produce only CTC or both varieties of tea. This is evident from the standard deviation for the specific TD oil consumption which is over 90 per cent in case of factories producing only orthodox tea as compared to about 50 per cent for the other two categories of factories. Even in case of specific electricity consumption, the standard deviation is over 75 per cent for orthodox tea factories compared to about 26 per cent for the other categories.

There could be various reasons for the disparities observed. The analysis of detailed information collected from four tea factories and the general data obtained for all the tea estates point at the following reasons which could be the cause of these abberations.

1. It was indicated that some of the Mcleod tea estates use coal instead of TD oil. Since the analysis has been conducted based on the monetary value of the fuels consumed, the specific energy consumption would be lower in case coal is used as a fuel as it would cost much less compared to TD oil.

2. Specific TD oil and electricity consumption could vary considerably with the age and type of equipment used in the factories and their relative efficiencies. This variation would be more in case of specific TD oil consumption, since three different types of driers and burners are used at the Macneill and Magor tea estates. Electrical equipment are more or less standardized in terms of their rating and would consequently result comparatively uniform values of specific consumption.

3. In case of specific electricity consumption, disparities could again occur since the analysis has been conducted based on the monetary value. The specific consumption would be more for factories which operate with a higher percentage of self-generated electricity as compared to those which mainly operate on electricity purchased from the ASEB grid.

4. It was observed that in the data collected, domestic electricity consumption is included with the electricity consumed by the factory . Therefore, even at times of low production of tea, electricity consumption would be high on account of the domestic load. Similarly, tea estates which have a greater domestic load would register a higher specific consumption.

5. Specific energy consumption (of both TD oil and electricity) would also vary depending on the the operational procedures adopted by personnel at different estates, and the time duration over which they operate different processes such as withering and drying.

6. Another major cause of error could be in terms of reliability of data.

In this paper, an attempt has been made to indicate the disparities observed in the energy consumption of different tea factories. Some of the reasons for these are also given.

In the absence of a systematic monitoring system, it would be very difficult to obtain accurate data based on which a methodical analysis could be carried out. Only based on a careful and detailed study which takes into account factors such as those mentioned above, would it be possible to arrive at norms for energy consumption, or establish a benchmark based on which a comparative study of different tea factories could be carried out.

In view of the total energy consumption of all the tea estates, it is imperative that the framework for such a study be drawn and suitable action be taken based on the results of the analysis.

A routine analysis based on physical energy units of fuels and electricity, i.e., kJ or kcal would enable a better comparison of specific energy consumption (kJ/kg made-tea or kcal/kg made-tea) values. It is important to find reasons for disparities in these values between tea estates, take corrective action, and to set targets for energy saving.

Energy Conservation Concepts For Diesel Generators

by
Harish Hanagudu*

Introduction

Electric power shortage is widespread in our country, crippling normal operations of industrial units and reducing industrial productivity. Industries are thus forced to install captive diesel generators (DG) sets to augment supply and in many instances provide for the units' total power requirements. The number of captive diesel generator units installed has shown a rapid increase in the recent past, reflecting the deteriorating utility power supply situation in many states.

Almost all of the presently installed DG sets are designed to operate on distillate fuels, viz., HSD/LDO (High Speed Diesel/Light Diesel Oil). However, a few new sets being installed, will be operating on Heavy Petroleum Stock (HPS) and Heavy Residual Fuel Oil. The existing DG sets consume distillate fuels which are scarce in the country. Moreover, DG sets being critical equipment for the plant operation, are run for long periods. This leads to substantial costs being associated with the operation and maintenance of the DG sets. Hence, it is vital that adequate attention be provided right from inception, on selection, installation, operation and maintenance of these sets. Training should also be provided to the engine-room operators to appreciate the importance of the DG sets.

The note discusses the several issues related to the proper operation and maintenance of DG sets, leading to better performance efficiency, and fuel conservation.

Factors which affect the operation efficiency and fuel consumption in DG sets are listed below. Details explaining the importance of each of them is given. Possible methods and techniques of improving DG set efficiency are also provided. These factors could be classified as:

- Extent of Loading
- Proper Instrumentation
- Lube Oil Conservation
- Fuel Additives
- Waste Heat Recovery
- Maintenance procedures

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* Formerly with TERI

Extent of Loading

The extent of loading on diesel generators is a very important parameter in determining the efficiency of engines. Almost all diesel engines have low efficiencies at loads below 50 per cent. A DG set may often not be made to generate to its full rated capacity. If this happens, the fuel consumption per kWh generated increases. The increase will depend upon (i) the ratio of actual output to rated capacity; and (ii) design and capacity rating of the DG set. Figure 1 illustrates the observations made in a field test to study the change in fuel consumption of a DG set at different loads. Table 1 gives a comparison between the recommended and actual specific fuel consumption for DG sets of different capacities. The manufacturers' specifications of part load fuel consumption for different DG sets are provided in Table 2. Note the higher fuel consumption, when the sets operate at lower loads. At part loads at or below 50 per cent, the fuel consumption increases with increasing capacity of DG sets, and are higher than those of small DG sets.

However, there are instances where a DG set is unable to be loaded to its full capacity. This could be due to:

- Overheating of the engines

  It is recommended that the cooling circuit be maintained well, and water quality be tested to avoid scale deposition.

- Poor response of governors

  Due to the inertia and sluggishness of mechanical governors, DG sets are unable to respond to load changes. It is essential that the governor mechanism is maintained well.

Many operators experience the problem of not being able to detect higher fuel consumption or changes in parameters, due to faulty or improper instrumentation. It is hence absolutely essential to provide individual flow meters and other indicating instruments to detect the problem early and rectify them in time. Several plants do not maintain accurate records of HSD consumption in the DG sets. Only data relating to HSD purchased is available. No fuel management programme can take off unless the database is complete and sound.

FIGURE 1

A. Variable load Characteristics of Diesel Gen. Sets

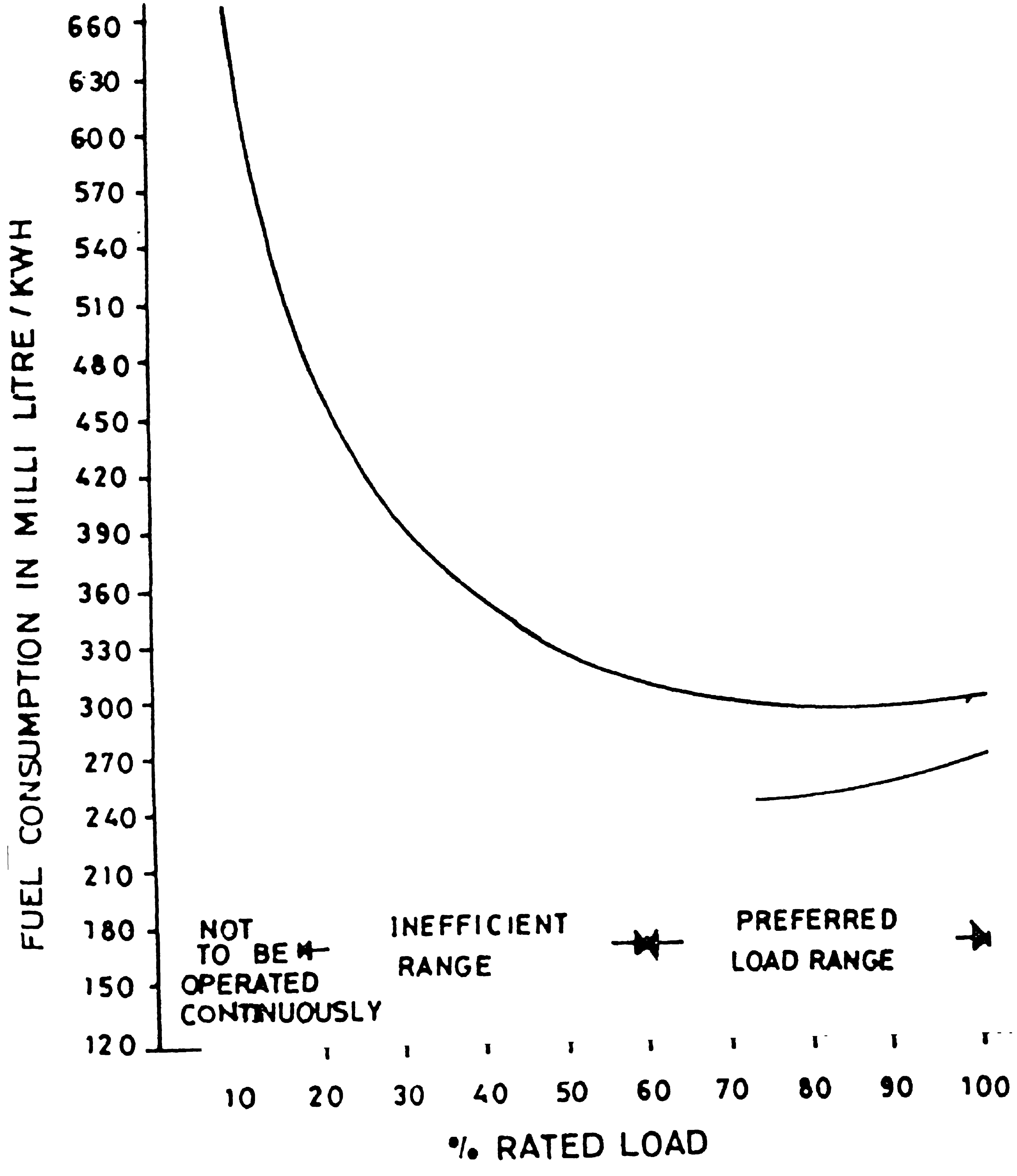

Table 1

Specific Fuel Consumption of HSD, Recommended Vs. Actual

Rating kVA	Recommended kWh/L	Actual kWh/L
1450	3.84	3.2
1100	3.88	2.7
625	3.73	2.7
608	3.50	3.47
550	3.50	2.64
500	3.84	2.64
400	3.69	2.26
310	3.30	3.28-2.96
250	3.20	2.7
180	3.07	2.8-2
175	3.0	2.7
166	3.0	2.55
160	3.0	2.5
120	3.0	2.38

Table 2

Implications of Part-Load Conditions on Diesel Consumption

Rated Capacity kVA	L/kWh of HSD for Various Loading Conditions, %			
	100	75	50	25
<100	0.2341	0.2404	0.2496	0.2617
320	0.2311	0.2388	0.2542	0.2750
1000	0.2301	0.2378	0.2531	0.2789

Source: Personal Communication, Kirloskar Cummins Ltd., New Delhi.

Lube Oil Conservation

Lubricating oils are consumed in large quantities by DG sets. An estimate by the Petroleum Conservation Research Association (PCRA) shows that around 10,000 tonnes of engine oils was used in 1986-87 for consumption in DG sets alone. Although the quantity of lubes used is much less compared to the HSD consumption, the price of lubes is nearly thrice as that of HSD. Therefore, lube oil conservation in DG sets is important. The consumption of lubes depends largely on the number of hours for which a DG set is operated, the speed of the engine and its size. Lubes have to be changed after a specified number of hours of operations.

Lubricating oil consumption is either due to top-up or oil change. Factors which affect the top-up and oil change are given below:

Top-up

The top-up oil consumption will largely depend upon:

- engine design - piston rings, clearances in valves, guides, etc.
- engine operating condition - speed and load, frequent start/stops

It is necessary to avoid overlubrication during top-up, as it leads to excessive viscous drag, and deposition of scales.

Oil Change

The useful life of lubricating oils is limited by the process of degradation and contamination. Degradation refers to an irreversible change in oil quality, e.g., oxidation. Contamination refers to a condition, where external unwanted agents have infiltrated into the oil.

Oil in service deteriorates due to degradation and contamination. At this stage the oil charge has to be replaced by fresh charge. The general practice being followed is to drain the oil at predetermined intervals. The interval is specified by the equipment supplier as number of hours of operation between oil change. The oil change intervals for different DG sets (as examples) are given in Table 3.

Table 3

Lube Oil Drain Intervals for Different DG Sets (Examples)

Brand	Installed Capacity kW	Recommended oil drain interval in hours of operation
SKL	500	1000
SKODA	400	500
RUSSIAN	35	500
CUMMINS	400	250

Table 4

Tests Required for DG Set Engine Oils

Test	Test Method	
Kinematic Viscosity at 40°C	ASTM	D445
Kinematic Viscosity at 100°C	ASTM	D445
Viscosity Index	ASTM	D2270
Total Acid Number	ASTM	D974
Total Base Number	ASTM	D664/2896
Water	ASTM	D95
Pentane/Benzene insolubles	ASTM	D893
Flash point	ASTM	D92

Source: Workshop on Diesel Conservation in Captive Power Generation (Background Paper), Confederation of Engineering Industry, New Delhi.

These specified intervals are based on the worst possible operating conditions and hence, provide a safe limit. If a user operates under less severe conditions and better maintenance practices, he is likely to discard oils when they are still good enough for use. Therefore, a scope exists for conservation of engine oil, if the drain period intervals are optimized based on operating conditions or oil is drained on a condition basis.

To arrive at an optimum drain period, test the oil for its key properties. These properties, along with the test methods are shown in Table 4. To implement these physico-chemical tests, a small laboratory facility may be required. On the basis of the results of the laboratory tests, decide whether to reduce, extend or keep the same drain interval. The cost of the facilities will be paid back within a short time from the savings accrued due to longer oil drain periods.

Fuel Additives

Generally, fuel additives are used only when a specific problem exists and when other conventional solutions have been exhausted. Fuel additives have been mainly used in boilers to improve combustion efficiency, inhibit high temperature corrosion, avoid cold end corrosion and formation of deposits. It is necessary to understand clearly both the benefits and potential disadvantages of the additives under consideration.

With special reference to fuel additives for improving combustion efficiency in DG sets, it may be noted that results of tests conducted by PCRA reveal that out of thirty additive suppliers, who all claim improvements in combustion efficiency, only one brand of additive after use has shown a slight improvement in the engine efficiency. The improvement is marginal, and efficiency of the DG set has increased by 2 per cent, in contrast to the manufacturers claim of 10-15 per cent. Almost in all instances, the additives are not cost effective.

Tests are still in progress to confirm the observed increase in efficiency. The effects of long-term use of an additive on the engine parts have not yet been studied; additives have to be checked for corrosion and fouling possibilities.

Waste Heat Recovery

DG sets operate in an efficiency range of 30-40 per cent. This shows that of the 100 per cent energy given by the fuel, only 30-40 per cent is converted to electricity.

The rest is lost as waste heat. The major sources of waste heat in a DG set are:

- Engine exhaust gases
- Jacket cooling water
- Lube oil cooling circuit

Various waste heat recovery equipment are available for the recovery of the otherwise wasted energy. The recovered waste heat could be used as a heat source in a few applications. Some of the possible applications are listed below:

- Preheat combustion air for heaters/furnaces near by
- Generate hot water for process
- Waste heat boiler for steam generation
- Vapour absorption refrigeration system for cooling
- Preheating stock for furnaces

Waste heat recovery schemes are viable only when large quantities of hot exhaust gases are available and on a continuous basis, i.e., large capacity sets or a cluster of smaller capacity DG sets. However, it must be noted that these schemes will have a reasonable payback only if the DG sets are being run for a larger part of the year.

Maintenance Procedure

Strict adherence to recommended maintenance practices will ensure efficient operation of the DG sets, as well as save fuel. A checklist of the important maintenance activities for DG set is provided below:

General

- Check for compression pressures and attend to stuck piston rings, leaky valves, excessive liner wear and ring wear, etc. promptly.

- Meet manufacturer's norms regarding parameters like cooling water, temperatures, back pressure, flow rate, etc.

- Ensure cleanliness in the generator room.

Fuel Injectors

- Check injectors once in three weeks, for leakage and spray pattern

Exhaust Valves

- Frequency of overhaul depends on exhaust gas temperature and impurities in air and fuel

Starting Valve

- Ensure proper closing of the valve after start. Drain the starting air tank regularly to prevent corrosion and leakage of starting valve seat

Pistons/Piston Rings

- Ensure proper cooling and lubrication; replace rings in time. Clear lube oil passages.

Heat Exchangers

Clean once in every 500 hours of operation, if hard water is in use. Water pH to be between 7-8.

Turbo Charger

Breather to be cleaned externally once in an hour, an internal surface once in 100 hours of operation.

Fuel and Lube Economy

Appendix 1 provides operating and maintenance tips for fuel and lube efficiency in DG sets.

Reference

- Confederation of Engineering Industry (1987), Background Paper, Workshop on "Diesel Conservation in Captive Power Generation", New Delhi.

- Waste Heat Management Guidebook, Federal Energy Administration (1977), Washington, U.S.A.

Fuel and Lube Economy

Appendix 1 provides operating and maintenance tips for fuel and lube efficiency in DG sets.

Conclusion

A systematic maintenance of DG sets at tea factories of Macneill and Magor would ensure efficient operation of these sets and fuel efficiency. In cases where old DG sets are used, it would be worthwhile evaluating the costs and benefits of newer sets which are much more energy efficient. In the existing sets, lube oil conservation would be attractive, which can be achieved through proper measurement of an various characteristics of lube oil to determine change frequency need.

APPENDIX 1

Diesel Generator Sets
Operating Tips for Fuel and Lube Efficiency

1. Select proper fuel. If injection system can tolerate more viscous fuels like LDO, furnace oil or other residual fuels like LSHS or HPS, go for higher viscosity fuels.

2. Ensure proper storage and handling of fuel. Dirt and contamination will make the fuel go off specification.

3. Load the DG set above 50 per cent for large D.G. sets, and above 60 per cent for small sets.

4. Ensure proper fuel injection, correct viscosity and temperature, timing, proper mechanical condition of components, and prevent lube contamination.

5. Select proper lubricant. Monitor lubricant condition through regular sampling and analysis of used oil. Ensure proper lubricant cooling and consumption. **(Thicker oil cause 2 per cent excess fuel consumption).**

6. Externally clean the air filters regularly, to ensure proper filteration and cleanliness of intake air.

7. Avoid leakages of fuel oil and lube oil, even though they may be of minor nature. They are a major cause for higher fuel and lube consumption.

8. Normally, engine oils of SAE 40 grades are used in D.G. sets, unless otherwise recommended by the manufacturers. Use of multigrade and higher performance level oils with high detergency, alkalinity reserve and antiwear properties help in both lube and fuel conservation in addition to improving engine mechanical efficiency.

9. Check compression pressure regularly if provision exists. Attend to stuck piston rings, leaky valves, clogged ports, excessive liner and ring wear, etc. promptly.

10. Insulate exhaust piping to reduce air temperature inside the generator room as the higher intake air temperature increases the specific fuel consumption and reduces engine output, **(Engine output reduces by about 5 per cent for 10°C rise in intake temperature)**
11. Avoid exhaust gas temperature above 450°C. High exhaust temperatures due to overload and restricted air supply, could lead to lower fuel efficiency as welll as fouling of turbochargers.

12. Avoid over lubrication to prevent deposits inside the engine and on the turbo-charger blades.

13. Maintain the cooling circuit system and clean heat exchangers regularly. Meet manufacturer's norms on cooling water temperature, back pressure, flow rate, quality etc.

14. Adopt preventive or preferably predictive maintenance programmes.

15. Attempt waste heat recovery, if technically and economically viable.

contd.

Diesel Generator Sets Measures for Diesel Engine Lubrication Oil Conservation

1. Improve air filtration

2. Reduce fuel dilution by

   a. ensuring proper atomization
   b. having correct engine temperature
   c. having proper air-fuel ratio
   d. ensuring proper crankcase venting
   e. eliminating worn out rings and cylinder liners

3. Check insolubles build-up in oil by using proper air, oil and fuel filters.

4. Reduce oil loss by proper clearnace between valve stem and guide

5. Reduce oil loss past piston by

   a. reducing carbon deposits on top land
   b. avoiding bore polishing and glazing
   c. attending to ring wear

6. Provide by-pass purification system or remove insolubles by centrifuging

7. Use long drain oils with improved air and oil filters

8. Monitor TBN values more closely where high sulphur diesel is used.

9. Switch on to multigrade oils for oil as well as fuel economy

10. Check for leaks in the lubrication system and attend to them promptly

11. Change oil on condition basis and not on the thumb rule recommended by oil companies or engine builders. Field oil testing systems are readily available in the country

12. Oil never deteriorates. It goes off specs temporarily. The drained oil can be re-refined and brought to proper level by appropriate re-refining and reclamation techniques. For further details on refining, consult PCRA booklet titled 'How to Conserve Lubes' (through recycling). For any further information on this, please contact PCRA, New Delhi.

Note: Oil refers to engine lubricant and fuel refers to diesel oil.

* PCRA - Petroleum Conservation Research Association.

PLUG-FLOW TYPE FLUIDIZED-BED DRIERS

by
G. Sambasivan

Fluidized-bed is essentially a layer of finely divided solid material through which an upward flow of air is induced. At a low superficial velocity, the air flows through the bed without significantly displacing solid matter. However, at a certain increased air · velocity, the frictional drag on each solid particle makes them get airborne, and in fact, the whole mixture of air and the solid particles behaves like a fluid. Hence, the term fluidized-bed. At certain air flow rate, the fluid layer isolates itself, as it were, from the bed.

The technology of heat propagation to tea leaves in fluidized-beds is characterized by a number of advantages. The thermal conductivity of a fluid is relatively higher due to simultaneous conduction and convection. This not only results in an efficient transfer of heat to tea leaves, but the air is incidentally used to arrest fermentation.

Plug-flow driers* which are currently available in our country are the second generation of fluidized-bed driers evolved to eliminate some of the drawbacks of conventional fluidized-bed driers.

Types of Fluidized-Bed. Figure 1 provides the concept of fluidized bed, and the various types of fluidized beds. The type of fluidization depends on the air volume, velocity and grid plate configuration. In anything other than plug (smooth) fluidization, solids are bypassed and the required uniform drop in temperature cannot be achieved. Apart from uneven drying, cross flow of tea leaves will take place and to some extent, the particle size will be reduced. This results in non-uniform product with lower quality level.

Plug-flow in a fluidized bed has some useful properties:

1. It looks like a boiling liquid and in many ways exhibits liquid-like behaviour. The upper surface of the bed remains horizontal throughout. This allows continuous automatically controlled operation with ease of handling.

2. The rapid mixing of solids leads to nearly isothermal conditions in each zone and hence, the operations can be controlled easily.

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* Supplier of Plug Flow Driers (known as Pandian Plug Flow Driers)	The Pandian Engineering Industries (Tea Machinery Manufacturers) Corsley, Kotagiri 643 217 The Nilgris, Tamil Nadu. Contact: Mr. G.T. Soundara Pandiaraj

3. Heat and mass transfer rates between air and tea particles are high when compared to other modes of contact.

Appendix 1 provides additional information on the Pandian plug flow dryers.

There is a basic difference between Macneill & Magor's driers and Pandian plug-flow driers. Whereas M&Ms have adopted the vibratory bed for the movement of tea, the latter use fluidized bed for the forward movement of tea. As such the air volume in plug-flow dryers include the fluidized component and the drying component.

These plug-flow driers are claimed to have perfect air distribution for optimum efficiency and also extract spent air without loss of tea.

While evaluating the drier, the economic consideration alone should not be the criterion, but the quality of the final product under comparable circumstances should be fully taken as the final proof of the drier performance.

Appendix 2 provides details of a standard 20 ft x 4 ft dryer of Pandian Engineering Industries.

Appendix 3 provides a copy of the letter from The Pandian Engineering Industries providing budgetary cost on the above sized drier.

Conclusion

The plug-flow driers have certain distinct advantages over the vibrating screen fluidized-bed driers currently used by Macneill and Magor. A complete evaluation of the former type of dryers should be done by M&M to determine the energy savings, capital investment, payback period, operating and maintenance expenses, dryer performance and other relevant characteristics. Only based on such an evaluation would they be able to decide if they could change some of their dryers, especially the endless chain pressure dryers, to plug-flow dryers.

APPENDIX 1

CHARACTERISTICS OF INDIGENOUSLY AVAILABLE PLUG-FLOW DRIERS

Construction

Pandian plug-flow drier chamber consists of three drying zones and one cooling zone made of heavy steel plates. The plenum chamber under the grid plate and the drying chamber have double-walled insulation to minimize heat losses. The top of the drying chamber is totally closed and two sets of cyclotrons, one for refiring and one for dust extraction are provided. The drive arrangements are totally enclosed to avoid tea dust and mounted under the endless belt conveyor. The aerodynamically designed high-efficiency fan is connected by means of a suitably designed air duct to the plenum at the feeding end. The precisely designed louvre type directional dampers provide the desired negative or positive movement to tea. At each zone, the required volume and pressure of air are controlled by independent air valves. A folding type of blow-hole suppressor made of stainless steel is provided in the drying chamber. This facilitates easy cleaning of the stainless steel grid plate. The inside walls of the drying chamber are lined with aluminium to avoid the tea coming into contact with M.S. parts. The fibre extraction cyclone can be mounted at a suitable place according to the convenience and space available in a tea factory.

Tea Dryer Heat Balance

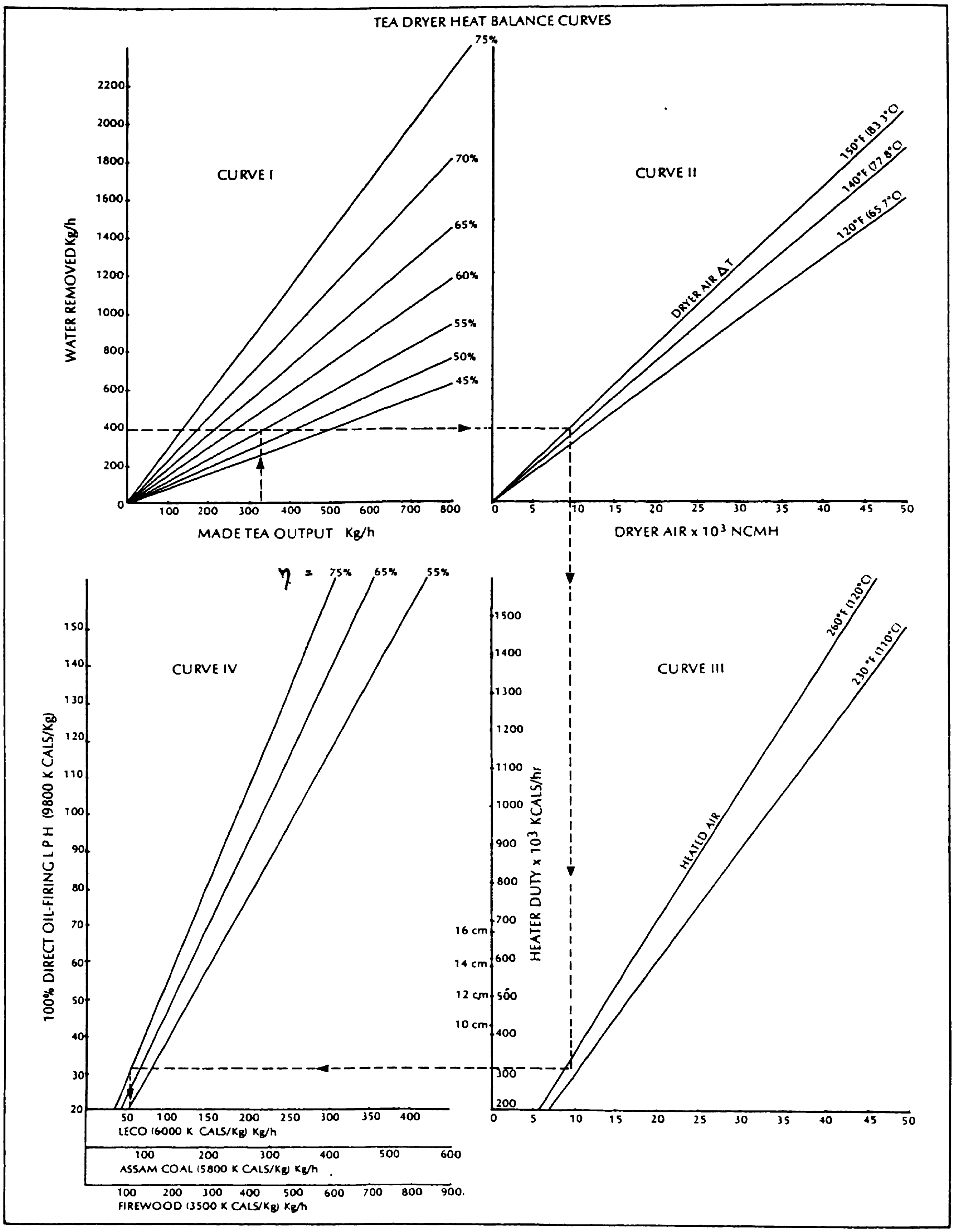
Pandian plug flow dryers are rated on the quantity of water removed in kg/hr. A reference to the tea dryer heat balance will give a clear picture of the approach.

Curve I gives the water removed in kg/hr for the particular made-tea output in kg/hr with varying feed moisture percentage.

Curve II is a plot of air quantity required against temperature drop in the dryer (ΔT) - temperature difference between inlet and final mixed outlet temperature. Plug-flow dryers effect 150-160°F temperature drop compared 130 - 140°F ΔT of the conventional dryers. Consequently, air requirement and power requirement are low for plug flow.

Curve III is a plot between air quantity and hot air final temperature with the heat duty of heater.

Curve IV directly gives the fuel such as firewood, leco or coal for each heater for different efficiencies. If oil-fired, direct-fired heaters are employed, their consumption can be directly read on the ordinate.



TEA DRYER HEAT BALANCE CURVES

The Pandian Engineering Industries
(Tea Machinery Manufacturers)
Corsley Kotagiri 643 217 The Nilgiris
GRAMS : PANDIND PHONE : 367

Some interpolations and comparisons

Indicated below is the performance of Pandian 325 C Dryer on the graph:

Made tea output : 325 kg/hr

Water evaporated at 55 % moisture level : 390 kg/hr

Dryer air at ΔT of $150^{\circ}F$ ($83^{\circ}C$) : 9.5×10^3 N cu.m/h

Heater duty : 310×10^3 k.cals/hr

Fuel required at 75% efficiency of heater : 55 kg/hr (Leco)

Pandian Special Heaters

These are specially designed heaters to give a stove efficiency of 75 per cent and above with a duty of up to 800×10^3 kilo cals/hr.

The following fuel-to-made-tea ratios have been obtained in practice:

Leco : 0.14

Firewood firing : 0.6

Coal firing : 0.2

Oil firing : 0.22 (North East India)

Assam coal firing : 0.5 (North East India)

Advantages of plug-flow driers:

- Elimination of underground tunnel
- Lesser horse power with increased efficiency of fan
- Inside parts of chamber in stainless steel
- Folding type blow-hole suppressors for easy cleaning
- Positive conveyor feeder
- Front discharge of tea
- Positive refining system with cyclotron dust separators
- Improved drying efficiency of 75 per cent
- Blacker and preferable teas with increased bulk density
- Briskness in liquor with brighter infusion

- With the reduction in cost of production and improvement in quality, the payback period can be less than two years depending on the production rate

Appendix 2

Details of Pandian Standard 20 ft x 4 ft Drier

1. Drier output : 500 kg. made-tea per hour.

   The Drier output is based on a 55 per cent feed moisture content. Under South Indian practice, it is customary to add tea to be reconditioned along with the leaf and this brings down the feed moisture to a desired level. The North Indian practice is different and the feed moisture may be higher at 75 per cent. In any case the quantity of water evaporated per hour is the criterion in deciding the output. In the case of the above drier it works to 650 kg water per hour.

2. Heat output : A 16 CM Heater or a 14 Super Heater having a heater duty varying from 600 to 700 x 10^3 kcal/hr for good satisfactory performance of the drier required.

3. Type of fuel required : Leco/coal/oil/firewood

4. Drier air temperature : 140°C

5. Feed moisture : 55 % and the outlet moisture of tea 3%

APPENDIX 3

The Pandian Engineering Industries
(Tea Machinery Manufacturers)
POST BOX No. 3

OUR REF:GTS:KAA/ 596 /Mach/90 20th January, 1990.

Mr. G. Sambasivan,
Fellow,
Tata Energy Research Institute,
7, Jor Bagh
New Delhi - 110 003.

Dear Sir,

We refer to our letter No. GTS:AKA/1223-Gen/90 dated 18.01.1990 and we give below our quotation for a 20' x 4' Plug Flow Drier for your budgetory purposes.

Description.

The Fluidised Bed Drier comprising of double walled insulated drying chamber, stainless steel grid plate, stainless steel blow hole suppressor, cold feed arrangements with ~~systems~~ endless food conveyor belt, cooling fan at the discharge end, fan with cooling chamber, hot air fan provided from the heater to supply the hot air fan for the 3 different zones in the chamber, cyclone with 2 fans which are provided one at the first zone to take the moist tea to refire in the end zone and the other at the 3rd zone to collect the fibre and reasonably minute particles of tea to the outside of the drying chamber. The whole machine is mounted above ground level. The cost of the machine includes motors, starters and switches, V-belt and cyclone dust separator with multicyclone system .. ..

Technical Details.

Tea Processing	:	South India CTC Tea.
Dryer size	:	Drying zone 20' x 4' Cooling zone 2' x 4'
Wither	:	75%
R.C.	:	100% on drier mouth.
Output possible	:	475 - 500 kg/hr.
Feed moisture	:	55%
Final moisture	:	3%
Connected load	:	59 H.P.
Feed point	:	Rear of drier with co-current flow and drying.

contd. .2..

Corsley, Kotagiri 643 217, The Nilgiris. Grams : PANDIND Phone : 367
TNGST.,RC. No. 291244 86-87 CST. RC. No. 342067 Dt. 1-4-1972

Commercial Details.

Basic cost of the Drier	Rs.	2,94,900.00
Hot air and cold air fan	Rs.	82,500.00
Electrical Motors total 34 H.P.	Rs.	46,600.00
Dust extraction system with multicyclone arrangements with a total of 25 H.P.	Rs.	1,55,000.00
Forwarding and Handling charges	Rs.	6,000.00
Erection, Commissioning and Supervision charges	Rs.	14,500.00
	Rs.	5,99,500.00

Terms and conditions:-

Note:- The ducting arrangement from the cyclone outlet will be done at extra cost.

Terms of Payment:- 50% of the value as advance with order and balance against delivery.

Period of delivery:- 2 months from the receipt of your firm order.

Delivery:- Ex-our works, Kotagiri.

Transport:- By your lorry on your account.

Basic Excise and Special Excise duty will be charged extra if it becomes payable at the time of billing.

Sales Tax @ 4% against 'C' Form.

Transit Insurance will have to be arranged by you at your cost.

A welding set should be provided by you at your cost.

Lagging work will have to be done by you at your cost.

Validity:- This quotation is valid only for 60 days from to-day.

Free accommodation should be provided for our mechanics at the time of erection at your cost.

Any masonary, electrical and carpentry works will have to be done by you at your cost.

Necessary unskilled labour should be provided for our mechanics at the time of erection at your cost.

contd. .3...

We hope that you will find our offer most acceptable and we would thank you to favour us with your valuable order which we assure you will receive our best and prompt services.

Yours faithfully,
For The Pandian Engineering Industries,

(PREM SAGAR PANDIARAJ)
Partner.

Fluidized-Bed Driers for Tea Drying*

Introduction

Fluid Bed technology first came into use towards the end of the last century, primarily as a means of pneumatic conveyance and transportation of materials. Around 1914 this principle was further extended for drying of materials by application of heat. Initially pharmaceuticals and chemicals only were dried in a batch process by using fluidized-bed technology. There has since been very dramatic extension of the concept and currently fluidized-bed drying is considered one of the most advanced, efficient and productive means of drying materials which lend themselves to fluidisation. Various types of materials including coal, sand, limestone, iron-ore, PVC (to name a few), are dried this principle.

As far as the tea industry is concerned, fluidized-bed drying is a comparatively new development. Most of the work in this field was done initially in Kenya and Sri Lanka during the late 60's and early 70's. Fluidized-bed driers as applied on tea, is a continuous process and was first introduced in India around 1980; since then they have become increasingly popular. Application of the drier to tea has resulted in the production of simpler, smaller, more efficient and compact units in terms of output, with far lower operating costs than the conventional endless chain pressure driers (ECP) which were first introduced in 1907 with only marginal improvements to date. Operational costs are particularly significant as drying is singularly the most expensive aspect of manufacture. In the ECP drier, drying is carreid out on perforated trays arranged in tiers and fitted on two or three endless bands continuously in motion. While these driers are robust and have successfully been used for three quarters of a century, their chief disadvantages are:

(a) Low fuel efficiency resulting in high operating costs.

(b) High maintenance cost consequent on number of moving parts such as chains, trays, etc. which require frequent replacement.

(c) Inconsistent firing of individual particles due to fall-through, uneven spread and also because of differential temperatures and air flow within the chamber.

(d) The machine once constructed has a fixed output which cannot be varied without incurring considerable expenditure towards modifications.

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* Extracted from Bedi, R., and Vasnaik, A.R., Fluid Bed Driers, Their Impact on Energy Conservation and Quality, Tea Today, Vol. 9, No. 1&2, 1988.

Description of Manufacturing Process of Tea

Green Leaf is plucked and withered both chemically and physically in conditioned air for a pre-determined interval of time dependent on ambient conditions of temperature and relative humidity. During this period the leaf cells are broken up and the enzymes allowed to concentrate. The process of withering also tends to dehydrate the green leaf to an extent of about 20-30 per cent of initial moisture in green leaf. Thereafter the withered leaf is subjected to other processes depending upon type of manufacture, i.e., CTC or orthodox. After completion of these manufacturing processes, the leaf is allowed to ferment again in conditioned air for a fixed time dependent on extraneous conditions. The leaf being very perishable in nature and susceptible to growth of bacteria, delays are not acceptable at any stage of processing. All the foregoing processes are very significant towards determining the quality of the product.

When the leaf has fermented for an adequate length of time it is fed into the driers wherein the moisture is removed under controlled conditions to leave a residual 2 - 3.5 per cent. Depending upon type of manufacture, and location and temperature conditions, moisture of fermented leaf can vary from 45 - 70 per cent. The residual moisture, however, is generally maintained constant within the parameters earlier expressed for all types of manufacture.

Drying has a very significant impact on the characteristics of the end product and should follow what has been established as the ideal drying curve for tea to maintain all desirable characteristics. In conventional driers drying time varies between 20-25 minutes. In fluidized-bed drying, the residence time or what is commonly referred to as "throughput time" is considerably reduced and can be controlled to between 9-15 minutes. the drying curve however remains unaltered.

Normally, the "constant rate" drying period is covered within 30 per cent of the drier length during which time the moisture content is reduced to approximately 10 per cent. Thereafter, the material goes through the "falling rate" period where it is very gradually dried to its final moisture level.

Principle of Operation of a Fluidized-Bed Drier

When a vertically rising stream of hot air is introduced at the base of a bed of fermented leaf, there exists a velocity of the air stream at which the individual particles will move within the bed. Each particle is surrounded by its own bubble of hot air and is suspended and agitated by the air stream. This stage is known as the onset of fluidisation or a state of incipient fluidisation increasing the velocity of the air stream thereafter will greatly increase the expansion of the tea bed. There is considerably relative movement of individual particles and consequently immediate and total mixing.

Movement of the individual particles in the air stream acquire many of the properties of a liquid and have analogous flow characteristics and hence referred to as a "fluidized-bed". Consequently, when more leaf is fed at one end, the leaf already existing in the bed which is partially dried tends to move further away from the feed and by the principle of displacement, and at a fully dried state will be expelled through the discharge end. However, in the case of vibratory bed driers, movement of tea within the drying chamber occurs as a result of the vibratory action of the grid plate.

Since each particle is conveyed in its own bubble of air, this promotes a very high heat transfer rate by a combination of convection and conduction. Such high heat transfer rates, especially when free moisture is present, result in almost instantaneous evaporation with constant rapid fall in air temperature above the fluidised bed. It is imperative however that the hot air stream velocity must be carefully controlled to yield optimum conditions in drying having regard to the particle size and its density. Each particle being surrounded by its own bubble of hot air, very little attrition of particles and abrasion is experienced. Because of free movement of the individual particles, mixing is substantinally instanteous.

The temperature throughout the bed becomes extremely uniform and it is not unusual for the material and the hot air leaving the bed at the discharge end to be of the same temperature. In the case of the fluidized-bed drier, a cooling chamber is provided wherein ambient air at room temperature is introduced by means of a separate fan to cool the tea before being finally discharged.

The Fluidized-Bed Tea Drier

The Fluidized-bed tea drier consists of a drive chamber with an integral hopper into which fermented leaf is emptied. From the hopper the leaf is conveyed through a feed conveyor into the drying chamber, the volume of which is controlled by means of a spreader over the trays. The feed chamber is independently driven with its own motors, gear box, etc.

Fermented leaf reaches the top of the tray conveyor and is then dropped on to a stainless steel distributor or grid plate at the base of the drying chamber. The grid plate has longitudinal perforations suitably designed to compensate for volume and pressure of air.

Beneath the drying chamber is a pressure and plenum chamber. Hot air is introduced in the drying chamber by means of a hot air fan which is attached to the heater through a duct leading into the plenum chamber. From the plenum chamber the hot air enters the pressure chamber via a series of velocity control dampers. The pressure chamber itself is bifurcated into partitions which are independent of each other so as to regulate pressure and velocity, as may be desired in each independent section. The air enters the grid plate beneath the drying chamber, the direction of which is controlled through a succession of flow control dampers which can independently be operated. The flow control dampers have a dual purpose - during operations their direction determines the residence time of fermented leaf in the drier, and at the end of manufacture they serve to evacuate the drier completely.

When fermented leaf enters the drying chamber it has a very high moisture content which is rapidly reduced within the first two sections. At this point maximum volume of air is introduced as rapid evaporation is desired. As the density of the material is at its maximum, velocity of the air passing through the distributor plate is relatively high and hence, there is an initial separation of fibre which is conveyed over the drying chamber into the dust extraction system. The fermented leaf within the chamber progressively dries and moves towards the discharge end which is fitted with the weir.

The main function of the weir is to control the residence time at initial starting. The weir is raised for about 2-4 in. to ensure that the tea is fully dried before it moves to the cooling chamber. Once equilibrium conditions have been achieved by use of the dampers and the weir, the weir is lowered thus permitting free access of drier tea into the cooling chamber.

As earlier stated, the cooling chamber has its own independent fan blowing ambient air which cools the tea before being discharged.

The system is provided with two temperature indicators, one located such as to monitor the temperature of inlet air and the other at a point midway in the drying chamber to monitor the temperature of the exhaust. The differtial between the two temperatures is a measure of the efficiency of drying, and it is desirable to maintain the minimum possible temperature difference between the two. Should the difference be large, it should be indicative of the hot air being underutilised and consequently the volume of fermented leaf can be increased through the spreader. The reverse is also true and if the temperature difference is too low, it is very likely that the tea will discharge at a higher moisture content than is acceptable. A via media has to be established with experimentation.

Some driers are provided with a dust collection chamber wherein fibres and very fine particles entrained in the exhaust air stream are deposited. Due to the density difference between dust and fibre, fibre is generally blown out of the drier and the dust with a mixture of heavier particles of fibre settle on a sloping floor/cyclones from where it can be collected.

Since hot air is continuously in contact with individual particles of fermented leaf and the fact that heat transfer efficiency is more, it is essential to fire the fluid bed drier at a higher temperature than is normally used on a conventional drier. Inlet temperature at 125°C is recommended. As a result of firing tea at a substantially higher temperature the leaf appearance is improved and the end-product tends to have a better bloom apart from being very much blacker in colour. However in static bed machines inlet temperatures can be varied from 160° to 138°C to meet specific liquor/end product requirement.

Salient advantages of Static Fluidized-Bed Driers

1. Fuel saving by virtue of more efficient heat transfer
2. Blacker tea
3. Superior bloom
4. Brighter infusion
5. Better liquors
6. Increased density of made-tea and consequent higher packing per chest
7. Uniform firing
8. Lower maintenance cost consequent on virtually no moving parts
9. Centralised controls

10. Greater output in relation to floor area

11. Decreased manpower requirement

12. Have total flexibility in operational controls

13. Static Bed machines can fire orthodox and CTC Machines.

It is important to note that while no specialised expertise is required for operation of a fluid bed drier, the principle however should be thoroughly understood. This is especially significant during the first half an hour of manufacture for setting of control dampers till equilibrium conditions are achieved. Thereafter the machine can continue to run normally without any further alterations to settings provided that moisture content of fermented leaf and inlet temperature remain constant, within limits.

Efficiency of fluidized-bed driers are between 60 - 65 per cent in contrast to 40 - 45 per cent on conventional machines. A fluid bed drier can be attached to existing heaters provided both are duly matched in terms of heat generation capacity of the heater. Driers can be operated with firewood and low-grade coal. The output of the system depends on two factors:

(a) heat generated which again is a function of calorific value of fuel used and the efficiency of the system.

(b) Evaporative capacity of the drier.

A very important point to note is that the weight or volume of moisture to be removed varies considerably depending upon the moisture content of fermented leaf. The table below indicates the amount of moisture to be removed in terms of litres to obtain 100 kg tea at drier mouth discharge at 2.5 per cent residual moisture (See Table 1).

New Developments in Tea Drying

As far as the driers are concerned, research is going on towards development of new concept machines using a spouted bed and flash drying techniques. These techniques will enable more effective evaporation during the constant rate period using higher temperatures without impairing quality of the end product. These driers would have an efficiency of the order of 80-85 per cent by virtue of increased heat transfer and more effective temperature control.